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EARLY MAN IN AMERICA WITH PARTICULAR REFERENCE TO THE SOUTHWESTERN UNITED STATES

INTRODUCTORY NOTE

THROUGH the interest of Dr. John C. Merriam in the subject of man's antiquity in the New World a symposium was held in St. Louis early in January, in connection with the meeting of the American Society of Naturalists. Dr. Merriam's interest in the subject under discussion is long-standing, and much of the work of recent years upon this problem has been carried on as a result of this interest.

It is fitting, therefore, that acknowledgment be made to Dr. Merriam for the opportunity he has given the authors of the following papers to correlate evidence, converging upon the problem of early man in America from many angles of approach, and for such grants as have been made from time to time by the Carnegie Institution. We are fortunate in having in America at this time some one who appreciates the necessity of bringing such evidence together, and who is in the position, quietly but effectively, to put such ideas into operation.

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THE ASSOCIATION OF A HUMAN CULTURE WITH AN EXTINCT FAUNA IN NEW MEXICO

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DISCOVERIES in the Southwest in recent years have done much to crystallize opinion regarding the length of time man has been in the New World. However, it is obvious that many more facts must be gathered before anything like a clear sequence of events, prior to the Christian Era, can be established. It is recognized that an absolute chronology is not essential; nevertheless, it is necessary for the ultimate understanding of American prehistory that the relative order of our earlier cultural complexes be more clearly defined. To follow the thread of the story of man prior to the Basket Makers of the Southwest becomes a complicated affair, involving factors having to do with geology and paleontology as well as archeology.

It is proposed to examine briefly here the problem of man's antiquity in North America with reference to the results obtained at sites near Clovis and Carlsbad, New Mexico. However, before doing this it may be well to take a brief glance at the discovery which has given the greatest impetus to work upon the problem in recent years, namely, that made near the little town of Folsom, New Mexico. This discovery was made in 1925 by local residents of Raton, New Mexico, and reported to J. D. Figgins, of the Colorado Museum of Natural History. In the course of the next few years careful work was carried on by the above museum and by the American Museum of Natural History, under Barnum Brown. Some thirty skeletons of an extinct bison and a number of highly specialized spearpoints were found in association under eight to twelve feet of restratified deposits. The spearpoints have come to be known as "Folsom points," the chief characteristic being a thin leaf-shaped

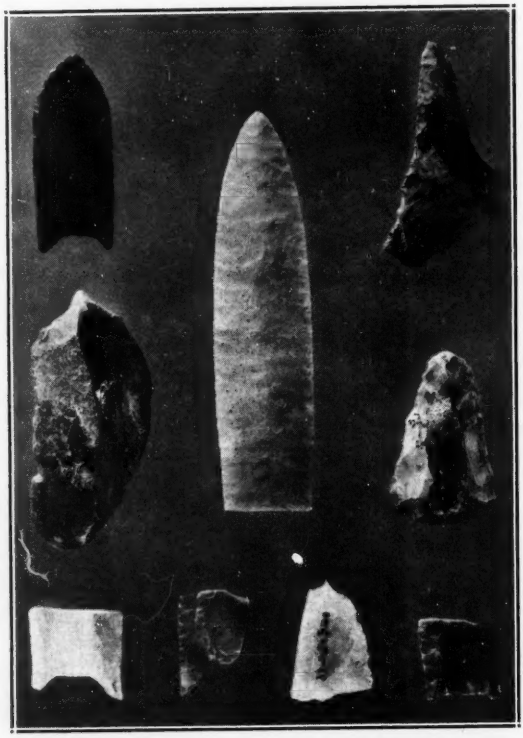
point, from the faces of which have been removed a longitudinal flake extending from the base nearly to the tip. This gives the spearpoint a biconcave cross-section. The base is a more or less flat concave, with ear-like projections. The secondary chipping shows a most remarkable control of the flaking tool, and these artifacts, together with those found under more or less similar conditions chiefly in Colorado and Nebraska, and known as "Yuma points," are second to none in the stone-flaking art.

To return to our main theme, first of all it may be mentioned that it seems to be generally accepted that man has been in this country for several thousand years before the beginning of the Christian Era—ten thousand years seems to be a conservative estimate, though there are those who are convinced that this estimate should be increased considerably. The evidence, however, at Clovis and at Burnet Cave, near Carlsbad, New Mexico, seems to point to a post-Glacial occurrence for the extinction of the animals and for such associated archeological material as was found there.

Some sort of time perspective is necessary, however, in order to derive a comprehensive understanding of the problem. One of our objectives should be to fill in the gap that exists between the Basket Makers and that time when people lived in the Southwest who made the so-called Folsom points, no matter whether this time element is represented by 8,000 to 10,000 years or double those figures. It is conceivable that there may be no connection between the postulated hunting stage of the Basket Maker and the Folsom hunter. Nevertheless, it is unlikely that man disappeared from the Southwest to reappear several thousand years later as an early agriculturalist known to us as Basket Maker II stage of that particular complex. We are not suggesting that the Basket Makers developed from a late stage of Folsom hunter; but we are wondering what belongs in between to fill this gap of some eight thousand years. Does the early cultural material of Gypsum Cave, for example,

and that of the lower level at Signal Butte, Nebraska, and others which might be mentioned, belong somewhere in this sequence? This will have to be worked out.

In bringing animals, such as those found at Burnet Cave and at Clovis, down to a period as late as 10,000



Types of artifacts from the Clovis Site. Central specimen 3¾" long.

years ago violence is being done to older notions concerning the extinction of such animals as the mammoth, horse, ground sloth, camel and so on, since it was previously believed that most of the Pleistocene forms had not survived the last glaciation. It seems to be difficult to support this idea any longer, for all the evidence of recent years tends to show that certain of the so-called Pleisto-

cene animals did survive the Wisconsin glaciation, and that they did not all die out at once as the result of some catastrophe, but existed in certain regions longer than others, even to within comparatively recent times.

The paleontological record gives us the chief clue for assuming the measure of man's existence in the New World to be in some thousands of years, and therefore it is appropriate to look to the paleontologist for a solution of the complicated problem of when these animals became extinct in that region we have been discussing.

The facts concerning early man in America, therefore, so far accumulated are not very great at best. Let us submit some of them and let them speak for themselves:

(1) Spearpoints, known as Folsom points, have been found in association with extinct animals in New Mexico and Colorado;

(2) These points are highly specialized and differ from the types made by the more recent peoples;

(3) No extinct animals seem to be associated with any Basket Maker people nor with any later peoples;

(4) Some stratigraphical evidence exists, such as that at Burnet Cave. Here evidence showed that the people who buried their dead in the cave and whose material culture resembles that of the Basket Makers of Utah, were later than those whose hearths and Folsom-like points were found at lower levels, associated with the bones of extinct animals;

(5) No human remains have been discovered up to this time that can be directly attributed to the makers of the Folsom points;

(6) Whereas, at the Folsom site itself only spearpoints were discovered, at the Colorado site and at Clovis, both of which represent subsequent discoveries, side scrapers, end scrapers, knives and gravers have been found in addition to the spearpoints;

(7) The geological evidence at these sites, including studies of the invertebrates and diatoms, point to climatic changes over considerable areas, where had been a some-

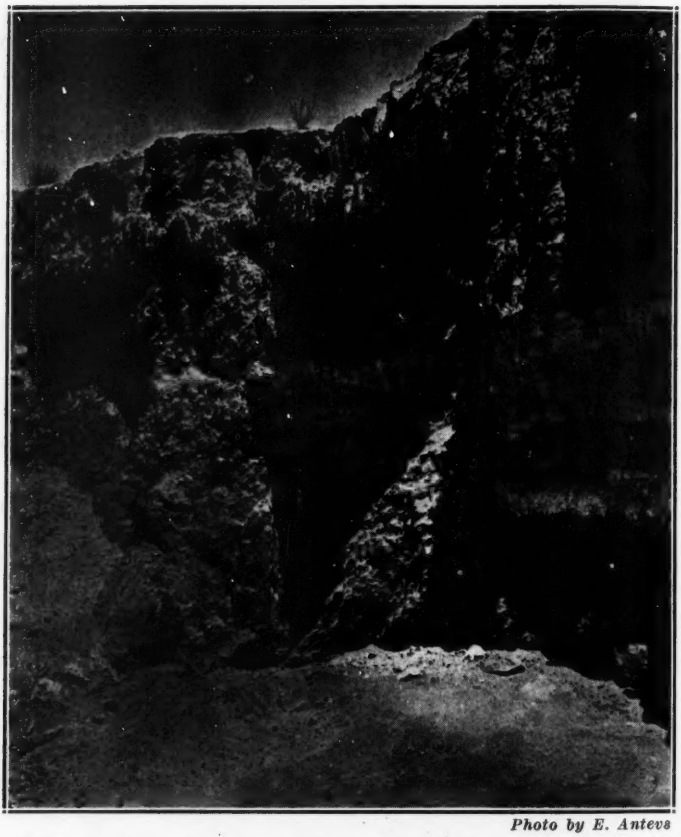


Photo by E. Antevs

Section in gravel pit, near Clovis, New Mexico, showing old lake-bed deposits, in which are found extinct animal bones and stone knives, scrapers and points. The upper three levels represent the bluish-gray sands and silts.

what cooler and less arid climate than now exists in those regions;

(8) In addition to the few sites where associations occur of extinct animals with Folsom points, are others where more generalized grooved types of spearpoints are found. This type, which has been called a Folsom-like point, is very widely distributed throughout the country, but, with

very few exceptions, points of this type represent surface finds.

This then represents an outline of most of the facts in the case around which to build up our picture of early man as we can see it at this time.

Certain questions immediately present themselves, and certain deductions may be made from an examination of these facts. After one grasps the idea that there were people living in North America at a period considerably earlier than the Christian Era, one is at once impressed with the fact that these Folsom points are made with the utmost skill and that they stand out as the finest examples of the stone-flaking art. One asks, therefore, how they can represent the work of our earliest people. One answer seems to be that they are not the earliest types in this country, having been, no doubt, preceded by other cruder forms which have not yet come to be recognized as such. On the other hand, the first immigrants from Asia, having reached the stage of culture represented by the Folsom flaking technique, may have brought this idea with them fully developed, in which case the Western Hemisphere would have lagged a long way behind the rest of the world in its original peopling. Some evidence is developing that the first answer will be found to be more nearly correct, namely, that there were antecedents of the Folsom people in America.

Another question that comes to mind on the heels of the one we have just been discussing is why we have not found Folsom man himself up to this time. It is more than likely that we have, but, since we are imbued with the idea that early man should exhibit characteristics considerably more primitive than our recent Indians, we have not yet been able to find anything in the way of remains sufficiently different to set him apart as Folsom man. No doubt, some of the narrow-headed skulls discovered in recent years belong to a people who may have lived about the time that Folsom man roamed across the plains in search of bison of a now extinct type, but physical anthro-

pologists have not yet given us the right to say that this can be established as a fact. Furthermore, as already pointed out, no human remains were found at Folsom nor at Clovis nor so far at the most recently discovered site in Colorado. Looking for the remains of Folsom man, therefore, is somewhat of a problem, since nothing is known as to whether he lived in the open in temporary shelters of some kind, or whether he was a cave dweller. The answers to these questions can only be speculated upon at this time. If he inhabited caves, then the dry caves of the region west of Folsom and Clovis, in the foothills of the mountains, should offer the best possibility of finding such remains, better, in fact, than the open site near Clovis, where there is evidence of a hunter of bison along former streams or basin areas that served as water holes for the herds and where the hunting problem was made easier by the circumstances. There is also the possibility that this early man did not intentionally bury his dead, all of which makes the finding of our so-called Folsom man largely a matter of chance.

By itself the occurrence of stone artifacts in the basin deposits near Clovis, together with quantities of bones of an extinct fauna, would not have excited much interest had it not been for the discoveries made at Folsom some six or eight years previously. This discovery furnished the impetus that led to the investigations at Clovis, when A. W. Anderson discovered the first point of this type at this latter place.

Though there is considerable difference in the geological features of these two sites, similarities of the stone implements and associations with extinct animals make it seem likely that the people who inhabited the two areas did so at approximately the same time—a time when climatic conditions were different than they are to-day in that region of the Southwest. The Folsom site covers a small area with relatively deep overburden, as compared to the thinner Clovis deposits that extend over a larger horizontal area. These latter are comparatively shallow

deposits occurring in the region known as the Staked Plains, offering almost as flat a profile as can be found, and resulting in little or no erosion, except by the wind, which blows the top sand into dunes. Such basins are known locally, and in fact, throughout most of the Southwest as sand "blowouts," and are ordinarily regarded as producing a mixture of archeological material that is hard to interpret in chronological order. However, a careful study often furnishes data of considerable importance. It is necessary to make a study of a series of basins over a large area, a careful examination of which reveals the fact that a sequence in the deposition of the archeological and paleontological material can be partially determined. This is true of the Clovis area and of the region around Boise City, Oklahoma, where the difference in composition of the deposits themselves and the unequal extent of erosion in the various basins are factors that can be related to certain types of artifacts and possibly to the paleontological evidence. For example, at Clovis we can observe three main divisions of the upper sands, the middle one of which is capable of further division and is known as

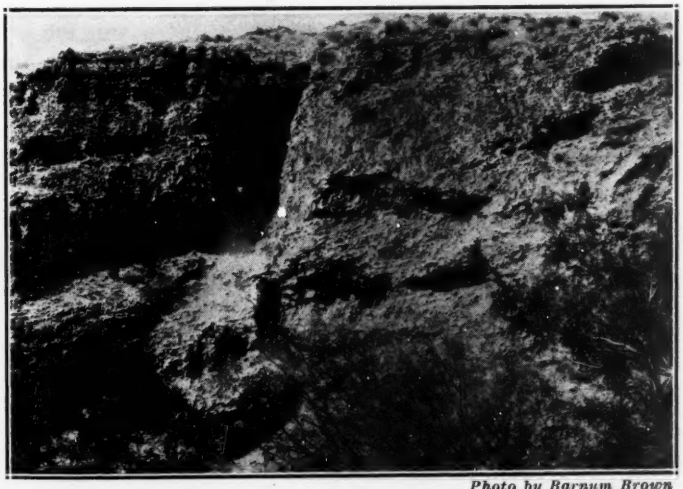


Photo by Barnum Brown

Burret Cave, near Carlsbad, New Mexico.

the blue-gray sands or silts. Of these three main divisions the top one is a loose brownish sand that is moved about easily by the wind, especially in dry periods; next comes the more resistant bluish-gray sand, and this is underlain by a caliche-like deposit that is seldom eroded in any of the basins. The archeological correlation at Clovis works out something like this:

(1) The Folsom and allied types of artifacts are not found in or on the top sands. They are found where the top sands have been blown away, exposing the bluish-gray sands, and they are also found, in greater numbers, in basins where these bluish-gray sands have been eroded.

(2) On the other hand, no campsites of more recent pottery-making people appear in basins where the blue sands are eroded.

There are exceptions to both of these statements, where one or two artifacts that appear to belong with the Folsom types have been found in more recent campsites, and there are a few instances where bits of pottery and a few artifacts more closely allied to Pueblo types have been found in basins where deeper erosion has taken place. However, it would seem to be safe to say that 95 per cent. of the Folsom and allied types come from the basins where the blue sands are exposed and eroded, while 95 per cent. of the Pueblo or more recent types come from basins where the blue sands are not eroded. Similar observations have been worked out in more detail in Oklahoma by W. E. Baker.

As has already been reported, so far, no Folsom points have been found in place at Clovis, but other artifacts have been found in the blue sands, which under some classifications would be called Yuma points, but which we have always believed to be Folsom knives. If we are correct about this, then I doubt whether any of the types from Clovis can be designated as Yuma types. The truth of the matter is we are not altogether certain what the relationship, if any, is between the Folsom and Yuma point, both names of which are so frequently linked together.

Of the paleontological material recovered from the basins near Clovis extinct bison bones occur all through the bluish-gray sands, as do bones of the mammoth, but the latter do not extend to the bottom of these deposits. Horse and camel bones occur at the top of the underlying caliche, and at one basin where a deep section was exposed by a road company, horse bones and one peccary tooth were recovered from even deeper. We may, therefore, ask if the bison and the mammoth lived on after the horse and camel had died out in that region? It begins to look that way.

As we have stated, then, there were found in the blue-gray sands of the Clovis basins, bison bones, elephant bones and objects of human manufacture. In at least one of the basins artifacts occurred three feet below elephant bones which were weathering out of the top of these deposits. Thus man seems to have been contemporaneous with a bison that is now extinct and with the elephant in that region.

At Burnet Cave, as we have mentioned, the evidence seems to indicate that man had lived in that area at an earlier time than the cave people who used the cave for burial purposes, as discovery of a Folsom-like point in association with extinct animals at nearly five feet below the burial levels showed. Hearths were found as deep as eight feet below the surface. Animals included an extinct bison, probably the same form as that discovered at Clovis, the antelope, horse, camel, musk-ox-like animals and a number of smaller mammals, the living forms of which live to-day in higher latitudes and higher altitudes, and in fact, are northern forms.

In conclusion, therefore, we should like to point out that, while the problem of man's antiquity in the New World is far from solved, each new discovery has brought fresh evidence, in recent years, to add to the general picture. We believe that Carlsbad and Clovis may claim a modest share in the attempt to solve this fascinating problem.

THE SUCCESSION OF MAMMALIAN FORMS WITHIN THE PERIOD IN WHICH HUMAN REMAINS ARE KNOWN TO OCCUR IN AMERICA[1]

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INTRODUCTION

THIS paper is divided into two parts with a view to presenting first some general considerations which merit attention in the present study of the succession of mammalian life for the later Quaternary and, secondly, some facts which relate more specifically to the title of the address. It is a pleasure to acknowledge my indebtedness to Dr. John C. Merriam for the opportunity to discuss these topics at a symposium on "Early Man in America," with particular reference to the southwestern United States, before the American Society of Naturalists.

GENERAL CONSIDERATIONS

Geological. It is important to recognize at the outset the necessity of establishing the succession of mammalian species and genera on the firm foundation of accurate position of these types in sedimentary deposits. No dependable chronology can be realized unless this is accomplished. Furthermore, the superposition of faunas can best be determined if we establish the superposition of the strata containing these assemblages. Much has been accomplished in this direction in the Middle West, where mammalian forms are found in deposits laid down during the several stages of glacial advance and retreat, featuring Quaternary history in this region. Unfortunately, however, it is too frequently true that at specific localities faunas are but scantily represented, and our information is frequently based on relatively few types rather than on complete or fairly complete faunas.

[1] Contribution No. 196, Balch Graduate School of the Geological Sciences, California Institute of Technology.

While deposits and faunas of the north-central states form frequently a part of a sequence that can be connected directly with the history of the great continental ice-sheets of the Quaternary, this is less readily accomplished in regions more remotely situated from the immediate fronts of the advancing or retreating glaciers. While there is perhaps no less direct means of identifying events as belonging to Quaternary time in the region now comprising the great arid Southwest, the geological and paleontological episodes which have been recognized are as yet disconnected in large measure from the sequence of events as established in the regions immediately adjacent to the glaciated areas.

Still farther removed from the fronts of what were the great Quaternary ice-sheets is the Californian region of the Pacific Coast province. Here the evidence of changing climatic conditions during Quaternary time is available in the high mountain country, as, for example, in the Sierra Nevada and adjacent regions. Elsewhere, oscillations of the land have been in part responsible for the development of many well-defined terraces. In addition to the evidence of considerable movements of the land surface during the Quaternary, movements which incidentally have continued down to the present, this period is marked by an unusually complete physical record to be read in terms of hundreds and even thousands of feet of sediments. Terrace accumulations contain marine faunas which suggest warm water or cold water facies and are frequently interpreted as belonging to interglacial or glacial stages. While no complete assemblages of vertebrates are known from deposits regarded as belonging to the early Quaternary, the later Quaternary has been singularly productive in such representations. Unique among these are the asphalt beds and faunas, as, for example, Rancho La Brea, McKittrick and Carpinteria. While extraordinarily rich in its organic record this type of deposit suffers, along with less noteworthy occurrences, in lack of definite placement with regard to a standard sec-

tion for the Quaternary. One of the larger problems therefore in the Southwest and Far West is the correlation of specific biologic and physical events and the accurate placing of these events in the record of Quaternary time.

In the problem of correlating Quaternary faunas and deposits it is readily recognized that alluvial, lacustrine, fluviatile and aeolian accumulations are of special importance because of their frequent wide distribution. Moreover, these may contain fairly complete representations of the animal assemblages in existence during the period of their deposition. The position of fossil materials in the stratigraphic sequence is generally clear and the occurrence of such materials, with reference to overlying and underlying deposits, readily determinable.

On the other hand, cave accumulations and the entombed life assemblages generally present discrete problems in Quaternary time. The relation of these occurrences to the history of the adjacent regions is in most instances established with difficulty or not at all. True, the time of their deposition may be recognized with reference to terrace development or to the laying down of a physical record elsewhere, but their chief importance seems to lie in the fact that the entombed organic remains point toward more or less antiquity and reflect to a certain extent the climatic conditions during the stage of their accumulation.

Cave and fissure deposits are distinctly local in their occurrence, the stratigraphic succession of sedimentary and organic materials frequently presents difficulties in interpretation, and the possibilities of disturbance and intrusion are apparently greater than in the case of sediments laid down over broad areas. However, by the very nature of their deposition and occurrence, cave accumulations often preserve organic records of unusual type. This is particularly true in caves which remain dry or essentially so for long periods of time. Thus, for example, in Gypsum Cave, Nevada, in Aden Crater and in Shelter Cave, New Mexico, and elsewhere, unusually well-pre-

served remains, including the skin, hair, horny parts of claws, dried ligaments and dung of creatures now extinct, like the ground sloth (*Nothrotherium*), camel (*Camelops*) and four-horned antelope (*Tetrameryx*), have been encountered. It is reasonable to expect other occurrences of this type in the arid Southwest, where present climatic conditions favor the preservation of such materials. Furthermore, the service which a cave may render as a shelter for or as an abode of man facilitates the preservation of a record of man's presence and activity which is not apt to be encountered elsewhere. Among the evidences of man's occupancy of such sites may be not only artifacts but also his skeletal remains.

Biological. No attempt to ascertain the succession of faunas for Quaternary time will prove successful in the long run unless critical study is made of all organic materials derived from deposits of this age. This implies extreme care in the identification of organic remains not only with regard to forms that are clearly referable to extinct species, but even more so in the case of those types considered as identical with living species. Moreover, identification of material should include, wherever possible, not only the more diagnostic parts of mammals, namely, skulls and teeth, but also various skeletal structures. The extent to which skeletal parts have been utilized in the study and identification of Pleistocene birds makes it reasonably certain that similar studies among mammals might be conducted with profit.

It is perhaps unnecessary to dwell upon the need of certainty in the identification of species and upon the importance of recognizing that specific determination or allocation of a fossil form to a living type leads to weakness in the structure of basic data when not fully warranted by available material. Because of the comparatively restricted geographic distribution of a subspecies and its possible indication as to life zone and climate, even greater care must be exercised in the identification of fossil or subfossil material as belonging to a living sub-

species. The fact that a certain subspecies occurs in the region where a fossil has been found furnishes in itself absolutely no basis for referring the latter to the former. Specific and subspecific determinations form the basis for faunal lists and the latter become of paramount importance in any attempt to establish correlations on purely faunal grounds.

And here it seems desirable to emphasize the need for close affiliation of the paleontologist with the vertebrate zoologist. Particularly in the study of those species among fossil forms which appear to be intimately related to or are identical with species living to-day, the vertebrate zoologist with his knowledge of the taxonomy of modern forms, geographic distribution, zonal arrangement and climatic indications of living species and of ecology is in a position to supply information of considerable significance in an attempt to place subfossil and fossil assemblages in their correct sequence in Quaternary time. The study of a fossil or subfossil fauna from a specific locality would unquestionably be enhanced if the Recent fauna of the area in which the locality occurs is also carefully examined and determined.

SUCCESSION OF MAMMALIAN FORMS

The most striking contrast between mammalian faunas of proven Pleistocene age and those of the Recent in the southwestern United States is afforded by the more formidable carnivores and larger ungulates. Thus among the carnivora prevalent during the later Pleistocene, the dire wolf (*Aenocyon*), the great lion-like cat (*Felis atrox*), the sabre-tooth cat (*Smilodon californicus*) and the short-faced bear (*Arctotherium simum*) no longer survive, although in several instances smaller types occupy comparable or somewhat comparable positions in the living assemblages. Similarly, within the heterogeneous group of ungulates, the Proboscidea, groundsloths, camels and presumably horses have disappeared with the coming of Recent time.

Two views may be entertained with regard to this contrast, namely—(1) the extinction of the larger mammals has occurred in a comparatively short time, or (2) a gradual extinction has taken place in which case some forms survived longer than others. Viewing this history in the light of the geological background one may conclude that the latter is a more tenable hypothesis. While the Pleistocene as a whole represents a critical period in geological history the physical events which transpired during the later stages of the Quaternary, in the passage from glacial to post-glacial time, have left the impress of gradual rather than abrupt change.

If we regard the succession of mammalian types for the later Quaternary as one in which changing physical conditions are accompanied by changing life with gradual extinction of those mammals characteristic of the Ice Age, we ought to find among the several faunas recorded from this stage of geologic time a gradual change in the ratio of living to extinct forms. Thus the sequence of intermediate stages from typical Pleistocene to typical Recent should be marked by a smaller and smaller numerical representation of extinct forms with a concomitant increase in numerical representation of living forms as the Recent is approached.

In recent years a number of assemblages have come to light which by nature of their stratigraphic occurrence, unusual preservation, constituency or for other reasons give evidence of position in very late Quaternary time. In some instances attention has been focused upon them because of the presence of man, either as an integral part of these assemblages or as a type whose position is closely related in time. Among examples which may be cited from the Southwest and West are Clovis, New Mexico; Gypsum Cave, Nevada; Conkling Cavern, New Mexico; and Pit 10 at Rancho La Brea, California. Sites where unusually well-preserved remains of Pleistocene types of mammals have been found, distinctly suggestive of a very late stage of occurrence, are Fillmore, Utah; Aden Crater and Shelter Cave, New Mexico; and Gypsum Cave, Nevada.

Not all the faunas from these several localities have received sufficient intensive study to make available complete faunal lists. However, enough is known regarding the faunas from the former localities to warrant the statement that among mammals which survived into the period of early man are the ground sloth (*Nothrotherium*), the mammoth (*Parelephas?* cf. *columbi* (Falconer)), the horse *Equus,* camels (*Camelops* and *Tanupolama*), bison (*Bison* extinct species) and probably also the peccary (*Platygonus*). To this list should be added, on the basis of unusual preservation, the antelope *Tetrameryx* and probably its associate, *Capromeryx.* The species represented by these types are not in existence to-day, and of the nine genera given in the list, seven are extinct. It will be observed that none of the large carnivores is listed.

On this score one addition should be made, namely, *Aenocyon,* definitely recorded from Conkling Cave. Presence of this genus with *Camelops, Tanupolama* and *Nothrotherium* in beds whose vertical succession contain also human remains suggests that among the several faunas which bridge the gap from typical Pleistocene to typical Recent, that from Conkling Cave represents one of the older stages. On the other hand, appearance of greater age may in reality be due to a late survival at this locality of a larger number of characteristic Pleistocene types than is the case elsewhere. Aid in the solution of this problem doubtless will come from an analysis of the remainder of the fauna, especially with a view to determining how many of the remaining mammals represent Recent species. This implies likewise a study of man himself, for we are here, as well as elsewhere, in possession of little information concerning the physical characteristics on which his specific determination is based.

Presence of species of mammals, which have survived to-day, in typical Pleistocene assemblages, as for example in that of Rancho La Brea, makes it reasonably certain that many similar occurrences are to be recorded from the

period in which man is found. Thus at Clovis, the skunk (*Mephitis mephitis*) and the prairie dog (*Cynomys* near *ludovicianus*) may be cited as examples.

DATING RECORDS OF EARLY MAN IN THE SOUTHWEST

DR. ERNST ANTEVS

Most records of early man in North America have been found on the southern Great Plains and in adjacent regions of the southwestern states, well to the south of the region of continental glaciation. They have been found in lake deposits, river terraces, loess beds and caves. They consist mainly of implements, rarely of skeletal remains.

Without exception the dating of the finds is difficult. The several extinct large mammals, found in association with human records, may suggest an antiquity of at least some 4,000 years, since they had disappeared before the age of the Basket Makers,[1] but the actual times of extinction or extermination are not established. There is no known means of building up an absolute late-Quaternary geochronology in the Southwest. Dates in years must be borrowed from northeastern North America and from Sweden. The datings must be carried out through correlations of epochs and stages in the Southwest with stages in the two regions mentioned. The only known basis for such correlations is climate and various changes and conditions induced by climate in the physiography, flora and fauna.

In regard to time measures, we have for the post-glacial epoch Ragnar Lidén's unpublished geochronology based on an annually laminated, or varved, silt now forming in bays on the west side of the Gulf of Bothnia, owing to a yearly spring flood and a moderate summer flow of the rivers rising in the mountains. This silt contains some

[1] Edgar B. Howard, *Museum Journal*, University of Pennsylvania, Volume 24, 1935, pp. 53–171. See pp. 138, 150.

8,500 varves, which give the duration of the post-glacial.[2] The last part of the late-glacial period is covered by Gerard De Geer's chronology of the ice release of Sweden, based on the varved glacial clay. This time scale, which is not published in its entirety, embraces a few thousand years. Part of the Younger late-glacial is also recorded by varved glacial clays measured by the writer in northern Ontario and northern Manitoba.[3] The Middle late-glacial, or the age of uncovering of southern Ontario which exactly coincides with the Algonquin stages of the Great Lakes, is estimated from these lake stages, other contemporary geological events and fragmentary varve records to represent roughly 10,000 years. The Early late-glacial, or the age of ice release of New England, is found by varve counts and estimates to comprise about 11,500 years.

DIVISION OF THE LATE-QUATERNARY*

Post-glacial 8,500	Late	4,000 years
	Middle	3,500—Temperature distinctly higher than to-day
	Early	1,000
Temperature as to-day		
Late-glacial 27,500??	Younger	6,000??
	Middle	10,000??
	Early	11,500?

* Late-Quaternary—age since the climax of the last glaciation; late-glacial—age of dissipation of the last ice-sheets; (last) pluvial period—correlative of the late-glacial, and probably of the latter part of the preceding ice advance; post-pluvial—correlative of the post-glacial.

These Swedish and North American geochronologies and time estimates have been tentatively combined by the writer. The correlation has been made by means of the long-continued, major fluctuations in the summer temperature. The ice release of the Scandinavian Peninsula may have been contemporaneous with that of northern Ontario. These chronologies and correlations and a time division, based on the great variations of the summer temperature, lead to the accompanying chronological table. The summer temperature is used as basis for both

[2] Ernst Antevs, *Geog. Review*, Volume 15, April, 1925, pp. 280–284.

[3] Ernst Antevs, Geol. Survey of Canada Mem. 168, 1931.

correlation and division for several reasons. Its major changes seem to have affected the entire, or most of the northern hemisphere. It is the chief factor in the growth and dissipation of the ice-sheets and in the fall and rise of sea level, as regulated by the accumulation and waste of ice. The summer temperature largely determines the latitudinal distribution of plants and animals.

In order to apply these geochronologies and time estimates to the Southwest, stages in this region have to be correlated with stages in the glaciated Northeast and in Scandinavia. Such long-range correlations can only be made by means of climate, and by means of changes and conditions caused by climate in flora, fauna, glaciation, deposition and erosion by rivers and rise and fall of lakes in closed basins.

The foremost basis also for these correlations is the summer temperature, for the same major temperature fluctuations have probably affected all the three regions. The second means of correlation is the precipitation. During the late-glacial age the correlation is based on compensating, not agreeing, precipitation. The decrease in snowfall over the ice fields, which was one of the two main conditions of the ice dissipation, seems to have been compensated in the arid belts around the globe, for there was a roughly contemporary increase in the rainfall of the deserts, and the total annual evaporation and precipitation throughout the earth may not vary greatly. It is essentially the location of the rainfall that changes. The nature of the relationship, during the post-glacial epoch, between rainfall fluctuations in the Southwest and in the Northeast has not been established. Nor is the relationship and correlation of the moist and dry epochs in northeastern North America and in Scandinavia well known. The correlation is complicated by the fact that the New England-Great Lakes states were released from the ice about twice as long ago as was southern Sweden.

In some cases correlation is based on temperature as well as on rainfall, because relevant climatic conditions

were the result of a cooperation of the two factors. The pluvial period was caused by a combination of increased rainfall and of diminished evaporation due to a drop in temperature. While the temperature lowering may have been practically the same in New Mexico and in Nevada, the increase in precipitation could have been different. As a consequence the culmination of the pluvial period, recorded by the highest lake levels, could have occurred at somewhat different times in the two regions.

As regards actual datings ancient human records in caves and in loess beds present considerable difficulties. The main clue to the age of such finds may be their association with extinct mammals, which themselves or whose chief forage plants required distinct climatic conditions. The present datings of some loess beds are open to doubt.

The dating of human remains and artifacts occurring in river terraces has better prospects. River terraces are formed by deposition and subsequent erosion. The requirements for these processes in the semi-arid Southwest are not well known, but the crucial point seems to be the relationship between the condition of the flood plain or river bed and the severity of sudden floods. When the Southwest was settled by white men nearly all the streams lacked a definite channel, but spread widely over valley flood plains, which contained meadows, swamps and groves or belts of cottonwood, willow and ash trees.[4] Evidently, the vegetation checked the flood waters, and not only prevented erosion but caused aggradation. Then, after 1860 in southern Colorado, southern Utah and northern Arizona, and during the decade 1880 to 1890 in southern Arizona and central New Mexico, the streams began cutting steep-walled channels or arroyos in their flood plains. At that time the vegetation cover on the flood plains had been retarded or destroyed by settlers and live stock—by grass and forest fires, wood cutting, overgrazing and trampling. In the depressions were ditches, wheel ruts and trails. Therefore, when heavy rains caused sud-

[4] Kirk Bryan, *Science*, 62: 338–344. October 16, 1925.

den, major floods, the unchecked rushing waters quickly enlarged ditches, trails and other vegetationless depressions into deep arroyos. At present most of the streams flow between vertical banks of alluvium from 10 to 100 feet high, and from a few feet to several hundred feet apart. The streams do not build up their beds, nor do they overflow their banks during floods, but rather deepen, widen and lengthen their channels. Erosion will probably take place as long as the gradient of the stream bed is steep, the channel small in relation to the greatest floods and the shrubs and trees in the arroyo remain insufficient to check the rush of the waters and hold the debris. When these conditions have changed, the channel will gradually fill up, and the flood plain will be restored and aggraded.

But arroyo cutting occurred before the arrival of white settlers. Retardation and destruction of the vegetation cover were then probably caused by excessive drought. Consequently, under natural conditions the streams may build up their beds during ages of moderate and severe drought, and erode during periods of heavy rains and full floods, following directly upon ages of pronounced drought. Because of local diversity in physiography and vegetation, and because of the spottedness of heavy rains, arroyo cutting may not begin at exactly the same time in all the valleys of a region, much less throughout the extensive Southwest. If natural conditions, undisturbed by white men and live stock, persisted to-day most of the wide valley flood plains of seventy-five years ago would perhaps still exist, for the modern climate in the Southwest is probably intermediate as regards rainfall when compared with the extremes during the last several thousand years. However, this is not known. Furthermore, it is not known how many ages of deposition and of erosion there have been during the post-pluvial period, nor on what basis these stages should be correlated with precipitation cycles in the Northeast and in Scandinavia.

Least difficult to date are finds relating to early man in beds or on terraces of pluvial lakes. The pluvial

periods were the outcome of heavier rainfall and lesser evaporation on account of lower temperature. An attempt to date the culmination of the last pluvial in New Mexico considers the relative extent of the last, or late Wisconsin, glaciation in the southern Rocky Mountains and in the Sierra Nevada, temperature and precipitation during the climax of the glaciation, the extent of the pluvial lakes, the amount of rainfall when heaviest, and the rate of evaporation from the lakes.[5] The pluvial period is found to have culminated in New Mexico about 15,000 years ago, while the mountain glaciation reached its climax roughly 25,000 years ago, and the modern climatic conditions may have prevailed in the region for some 10,000 years. The artifacts, including Folsom points, which occur in association with "cold" mollusks and bones of mammoth and extinct bison in lake clays at Clovis, New Mexico, are perhaps 12,000 to 13,000 years old. My present studies on the late-Quaternary climate of the Southwest should enable closer time estimates.

Absolute dating of late-Quaternary deposits, climatic stages and records of early man in the Southwest has only commenced. Research should concentrate upon river terraces, pluvial lake terraces and beds, organic remains and deposits in general and peat in particular, loess deposits, the postpluvial history of closed basins and the variations of mountain glaciers. These deposits contain the remains of man and his activity and are, together with the stated events, most likely to reveal climatic features which could promote correlation with more or less dated stages in the Northeast and in Sweden. Since the datings in the Southwest depend entirely upon our knowledge of the geologic history of the regions of continental glaciation, further investigations in the northern states and in Canada on late-Quaternary time, climates and correlation with Sweden are also necessary.

[5] Ernst Antevs, Proc. Acad. Nat. Sci. Philadelphia, 87: 304–312, 1935.

RECENT DISCOVERIES OF THE MATERIAL CULTURE OF FOLSOM MAN

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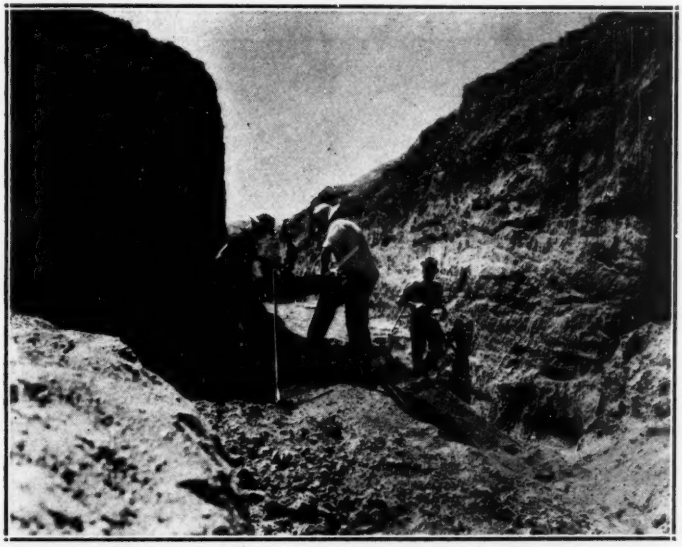
INVESTIGATIONS at the site that yielded the first definite complex of stone implements attributable to so-called Folsom man came as the culmination to an interesting series of events which began in May, 1934. In that month Mr. D. I. Bushnell, Jr., collaborator in anthropology at the U. S. National Museum, discovered in two collections gathered from various parts of Virginia examples of the type of projectile point which has been called Folsom. Announcement of the fact was made by the Smithsonian Institution in one of its press releases. The article, with photographs of the specimens, was printed in slightly revised form in the *Literary Digest* for June 9, 1934. This notice loosed a veritable flood of letters, and queries poured in from collectors all over the country. There was some confusion about what constituted a Folsom point, and the editors of the *Digest* felt that a second article, one describing its characteristics in detail, was advisable. In response to a request from them the writer prepared a statement, which appeared in the issue for July 28. The latter brought letters from many parts of the United States from people who had examples of the Folsom type. Among the letters were several which were received indirectly. Major Roy G. Coffin, professor of geology at Colorado State College, Fort Collins, had on two occasions, prior to the *Digest* articles, written to Dr. John B. Reeside, Jr., geologist in charge, section of stratigraphy and paleontology, U. S. Geological Survey, concerning a site in northern Colorado. At that place he and a brother had found a considerable number of Folsom points, several other kinds of chipped implements and indications that the tools had been made on the spot. Following the appearance of the second *Digest* article, Major Coffin

again wrote to Dr. Reeside, and the information was transmitted to the Bureau of American Ethnology. Several letters were exchanged between the writer and Major Coffin, and as a result of the correspondence it was decided that a first-hand inspection of the site was advisable. In September, 1934, the writer was sent to Fort Collins. The owner of the land, Mr. William Lindenmeier, Jr., gave permission for a series of investigations, and preliminary prospecting was started.

The site is north of Fort Collins, just south of the Wyoming line. It is located on an old valley bottom which, due to the eroding away of the ridges which once bordered it along one side, now constitutes a terrace above an intermittent tributary to a series of streams which ultimately join the South Platte River. It was first discovered in 1924 by Judge C. C. Coffin and his son, A. L. Coffin, two years prior to the original discoveries at Folsom, New Mexico. Since then they and the major, with various friends, have visited it from time to time and have collected numerous specimens. When the writer first went to Fort Collins they had gathered 83 points or portions of points and about the same number of other artifacts. From the very beginning of their finds the Coffins were convinced that the points picked up at this location were different from the usual Indian arrowheads which are so abundant in the general region. Although they recognized that they constituted a distinct type, they were not aware of their true significance until Dr. E. B. Renaud, of the University of Denver, told them they were Folsom points. In the summer of 1930 Dr. Renaud and a number of students, under a project sponsored by the Smithsonian Institution Cooperative Fund, the University of Denver and the Colorado Museum of Natural History, were making a survey of local collections and of former village sites in Colorado and adjacent regions. Their purpose was that of plotting distribution maps for various types of implements and the places where they were found. It was during these investigations that the

Coffin series was noted. In June, 1931, Dr. Renaud visited the location from which the artifacts came, and he describes it briefly in one of his reports. No digging was done, however, although portions of two Folsom points were picked up from the surface at that time. The Coffins continued their visits, intermittently, and added specimens to their collections. Most of the material was picked up from the surface, but a few pieces were

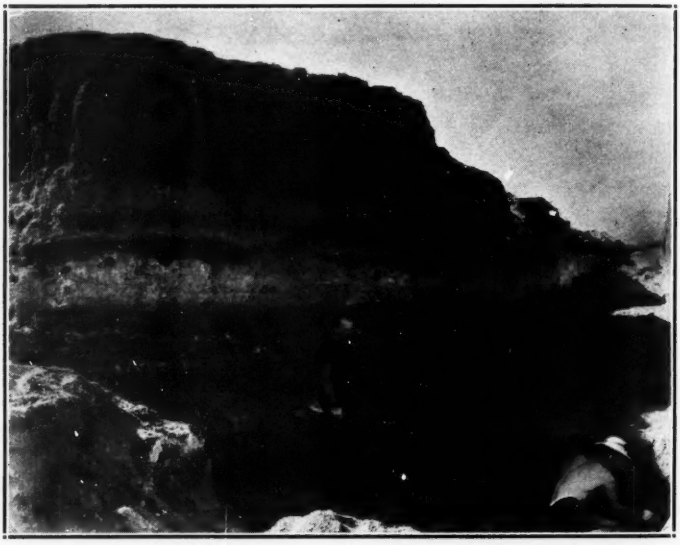


Working out material from upper layers in the main trench at the Lindenmeier Site.

scratched out of the soil. No extensive work was attempted until the autumn of 1934.

The place where the points and other implements were found by the Coffins is a denuded area approximately 70 by 150 yards in extent. The bulk of the material came from a small section covering only about 30 square yards. The surface over a greater portion of this section of the site is the top of a hard, compact layer of tufaceous clay, an Oligocene deposit. The artifacts recovered from it

had undoubtedly been in top layer material which was eroded away by wind and water. The implements because of their weight had remained until picked up. In some places portions of the sand, gravel and nodule layer which had overlain the compact deposit remained and the Coffins found a few objects on the contact line between the two. This part of the site did not seem to offer any particular inducements for digging, especially from the view-point of finding objects *in situ*. At the close of the



Lower end of main trench. Men are scratching for objects in artifact-bearing stratum.

first day's inspection the writer was not sanguine over the prospects for obtaining information beyond that already secured by the judge and the major.

On the second day, however, when Judge Coffin, his son and the writer were exploring the adjacent terrain the judge picked up a fragment of a Folsom point along the bank of a ravine which cuts through the terrace some distance above the original site. Close inspection of the

precipitous bank in the vicinity of this find revealed an undisturbed and intact layer of midden material 17 feet below the present ground level and 12 feet above the bed of the gully. A brief investigation demonstrated that the deposit, which is a quarter of a mile away from the spot where the majority of the Coffin specimens were found, was a likely place for excavation. Work was started and continued through the month of October and into the first part of November. Some digging was done at other portions of the site, but the major activity was restricted to the deep pit in the gully bank where most of the specimens were found.

In the spring of 1935 the writer returned to the site, and from the first of June until early September, assisted by a group of from 7 to 12 students, conducted a series of investigations. The plan of procedure for 1935 called for the digging of two large trenches through the section lying between the edge of the terrace and the ravine. The trenches were started several hundred feet apart, at points on the edge of the terrace where fragments of bone and stone chips had been found the preceding autumn, but were directed so that they would converge at the deep pit where most of the previous finds were made. This method of digging was adopted for the purpose of exposing a complete cross-section of the fill in the old valley bottom and determining, if possible, where the artifacts in the deep deposit had originated.

Only one trench was carried through to completion. The other was stopped when it became apparent that the evidence from it would merely duplicate that from the first one. The completed trench was 280 feet long and 10 feet wide, and sloped from a depth of 3 feet at the edge of the terrace to 17 feet in the bank of the ravine. The bottom followed the old soil level, which was the surface of the ground at the time when the site was inhabited by the makers of the tools found there. The trenches were dug in 10-foot sections and all the material from each was so designated. In addition the positions of specimens

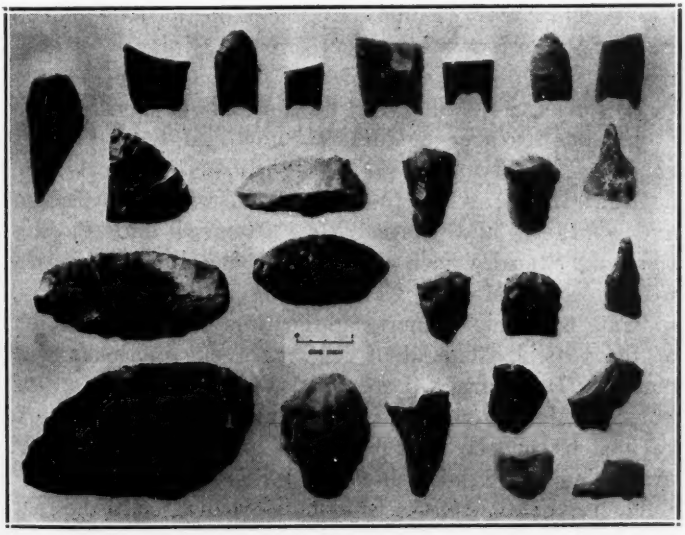
with respect to their location in the section were carefully noted. Detailed drawings were made of the faces in each section and these give a minute record of events involved in the growth of the valley fill.

Additional work was done near the location of the original Coffin finds. Trenches were dug through a portion of the area where some of the top level was still in place. This was a fortunate procedure because, contrary to the impression of the previous fall, there was evidence still in place. A bone pile comprising the remains of some nine individual bison was located there. Some of the skeletons were partially articulated. In one of these, when the vertebrae were being removed, the tip end of a projectile point was discovered *in situ* in the foramen, the channel for the spinal cord, of one vertebra. As this bone was in position in the center of a group of articulated vertebrae there was no possibility of the point being a later intrusion and postdating the skeleton. This association established beyond the shadow of a doubt the contemporaneity of the implements and the bones, a feature

Bison jaws (*Bison taylori*) in situ.

which has been questioned. The bison is one of the extinct species, *Bison taylori.*

The digging at the site has yielded over 1,000 stone implements and a few ornaments, one of carved bone, as well as bones from animals whose flesh or skins had been used by the one-time dwellers at the site. No human skeletal material was found, and although bits of charcoal and ashes were encountered no indications of a shelter or habitation were observed. The presence of hammer stones and numerous flakes and chips at several places indicated that one or several individuals had been seated there while shaping tools out of rough stone nodules. Pieces from a number of projectile points, as well as other tools, which had been broken in the making, were recovered from one such spot. By fitting the fragments together and restoring the flake to its original form it is possible to gain good evidence on the technique used in their manufacture.



Characteristic implements from the Lindenmeier Site.

The implements found consist of characteristically fluted Folsom points, snub-nosed scrapers, side scrapers, end scrapers, a variety of cutting edges, drills, gravers, rough-flake knives, large blades and sandstone rubbing stones. Similar tools have been found at various surface sites, but this is the first evidence to demonstrate that they belonged to the Folsom complex. The artifacts show that the lithic component in the local cultural pattern was primarily a flake industry, only a few implements of the core type being found.

Animal bones in the collection represent the fox (*Vulpes velox*), the wolf (*Canis nubilus*), the rabbit (*Lepus townsendii campanius*), the deer (species not determinable but presumably one of the larger forms), and the bison (*Bison taylori*). Of these forms only the bison belong to an extinct species, the same as that found at the original Folsom pit.

Invertebrates from the site include nine species: *Gastrocopta armifera* Say, *Gastrocopta ashmuni* Sterki, *Pupilla muscarum* (Linne), *Pupoides inornatus* Vanatta, *Pupilla sonorana* Sterki, *Vertigo* sp., *Valonia gracilicostata* Reinh, *Succinea avara* Say, *Zonitoides arborea* Say. Seven of the nine live in the region to-day, but two of the species are considerably north of their present range. These two are *Gastrocopta ashmuni* Sterki, the northern limit of which to-day is Grand Canyon, Arizona, and southern and central New Mexico; and *Pupilla sonorana* Sterki, whose present northern limit is in Mora County, New Mexico. This occurrence may, possibly, indicate a warmer climate at the time of the deposition of the fossils. The identification of the mollusks was made by Dr. Horace G. Richards, research associate of the New Jersey State Museum, and his findings were verified by Dr. H. A. Pilsbry, of the Academy of Natural Sciences, Philadelphia.

The importance of the Lindenmeier Site lies in the fact that it presents an occupation level which can be assigned to the Folsom people, and from it has come a definite

complex of associated implements. The last few years have been marked by much loose talk about the "Folsom Race" and "Folsom Man," when all that was actually known was the characteristic type of projectile point. The material from the Lindenmeier Site gives us the right to speak of a Folsom Complex, but from a strictly anthropological point of view it is still incorrect to speak of "Folsom Culture," because the remains so designated probably should be considered only as one aspect of a basic, wide-spread, early hunting pattern which may have extended across the eastern half of the continent.

Dr. Kirk Bryan, of the Division of Geology, Harvard University, and two assistants spent the month of July studying the geology of the district in an effort to determine the age of the deposits. No definite conclusions have been reached as yet, and for that reason it has not been possible to date the period of occupation. Archeologists generally concede that the Folsom Complex belongs to the earliest phase of aboriginal culture yet discovered, in North America. The supposition that the various types of implements represent considerable antiquity rests upon their association with the bones of extinct species of animals, the bison at this site, mammoth and musk-ox at other locations. Whether the finds actually date man in North America at the beginning of the Post-Glacial period or demonstrate a later survival of Ice-Age animals is a phase of the problem which the geologists and paleontologists must solve.

A PLEISTOCENE LAKE IN THE WHITE RIVER VALLEY

PAUL MACCLINTOCK, E. H. BARBOUR, C. B. SCHULTZ AND A. L. LUGN[1]

INTRODUCTION

DURING the course of a field conference on the Pleistocene geology of western Nebraska, varved sediments were found in the headwater drainage of White River near Crawford, Nebraska. A reconnaissance of White River Valley revealed them to be present also in the mid-course, near Interior, South Dakota, and at the mouth, near Chamberlain, South Dakota, where the White River joins the Missouri (Fig. 1). These isolated occurrences of

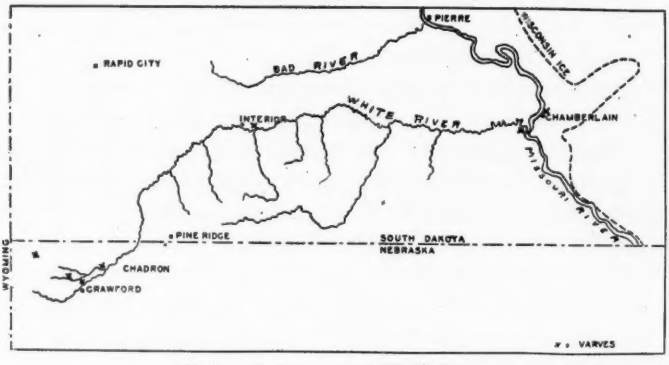


FIG. 1. Index map of White River.

varves, over a distance of 240 miles, are so similar that a correlation seemed possible. Furthermore, since the varves occur within the area where Yuma artifacts are found, it was thought that there was a possibility that they might be of assistance in dating the artifacts.

[1] P. MacClintock, of Princeton University, financed by a grant from the Carnegie Institution of Washington; E. H. Barbour, of the Nebraska State Museum; C. B. Schultz, of the Nebraska State Museum; A. L. Lugn, of the Department of Geology, University of Nebraska, and the Nebraska State Geological Survey.

Description

Everson's Site. The valley of Sand Creek north of Crawford in Dawes County contains varved lake sediments which were found in two places during the present reconnaissance. The westernmost locality is in the center of Section 36, T. 33 N., R. 53 W., Dawes County, one mile east of Everson's ranch house (Fig. 2). Here Sand Creek and its tributaries have partly dissected the gravel-capped surface of the Chadron clays into badland topography, in the lowland valleys of which varved, slackwater

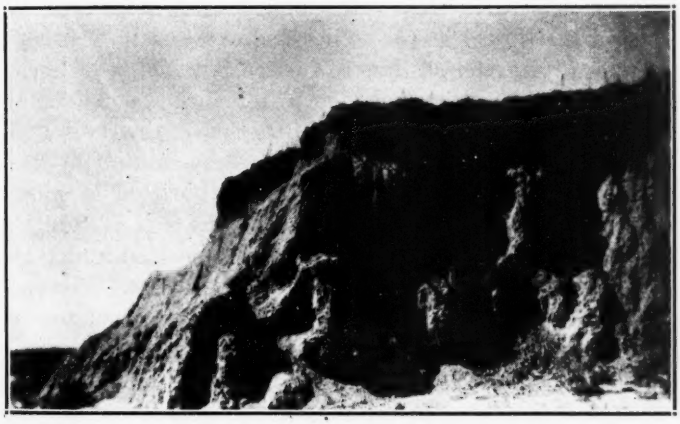


Fig. 2. Varves one mile east of Everson's house.

and alluvial deposits have accumulated. However, the evidence is clear from the presence both of buried soils and of trenches through the deposits, later filled by younger materials, that there has been quite a succession of events during the accumulation of valley fills. One of the episodes was that of a lake in which the varved sediments were deposited. The relation of the deposits is shown in Fig. 3. The sequence of events seems to have been as follows: The gravel-capped surface of the Chadron clay was eroded and gravel let down into the valley so formed, making a veneer on the valley walls, as well as patches in its bottom. Then followed an episode dur-

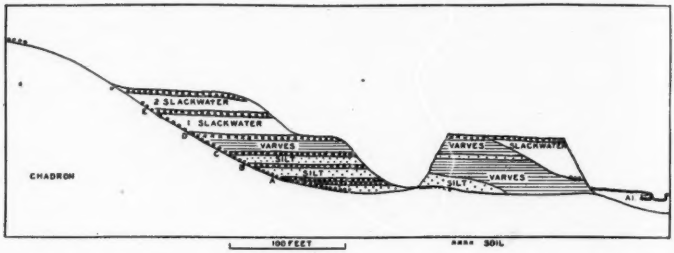


FIG. 3. Diagrammatic cross-section of Sand Creek one mile east of Everson's house.

ing which structureless silt (loess ?) was deposited to several feet in thickness. This was exposed to weathering for a long enough time to form a few inches of black soil, over which was deposited 6 to 8 inches of silt, and it, in turn, weathered to a soil. In Fig. 3, this twin soil zone is specified as Soil A. More will be said about this twin soil later. Then followed the deposition of more structureless silt (loess ?) and the formation of Soil B, about 1½ feet thick. Again silt was deposited and then weathered to Soil C, which is 2 to 3 feet thick. Erosion then trenched the silt and soil succession at least to the depth of the present valley, cutting it into small buttes and sharp valleys, much like those of the topography of to-day. After this followed the deposition of the varved sediments. It is obvious from their horizontal parallel bedding that they are lacustrine in origin. They are composed of alternating thicker layers of silt and thinner layers of very dark gray, greasy, smooth, fatty, colloidal clay. A two-foot structureless silt layer separates a lower series of varves from an upper series. Then followed an episode of weathering to produce Soil D on the varved sediments, and for a third time, erosion trenched all the deposits to the depth of the present valley. An episode of slackwater deposition ensued, filling up the depressions in the varved sediments and overlapping them against the valley walls. This deposit consists of finely stratified and laminated silts and fine sands so uni-

formly bedded as to suggest that quiet water conditions must have existed at the time. These first slackwater beds were then weathered to Soil E. A second series of slackwater beds were then laid down, which were weathered to Soil F. And finally, erosion dissected the whole series to the present topography with recent alluvium occupying the valley bottoms.

This somewhat complicated story may be summarized as a sequence of events or episodes as follows:

(1) Formation of gravel-capped surface.
(2) Valley cut and gravel let down as a veneer.
(3) Deposition of the silt (loess ?) sequence with interruptions long enough to weather the Soils A and B.
(4) Weathering of the silt to Soil C, and erosion.
(5) Deposition of the varved sediments.
(6) Weathering (Soil D) and erosion of the varves.
(7) Deposition of the first slackwater beds.
(8) Weathering to Soil E.
(9) Deposition of the second slackwater beds.
(10) Weathering to Soil F.
(11) Erosion to present topography.
(12) Deposition of lowland alluvium.
(13) Slight trenching of alluvium.

The measurements of the varves are plotted in Fig. 7. Many invertebrates and vertebrate fossils are found in the soil layers.

FIG. 4. Sand Creek Valley east from Highway No. 2 bridge.

Sand Creek Bridge. Varved sediments are seen against the south valley wall and compose part of a small isolated butte in the valley to the east of the highway bridge (Route No. 2 from Crawford to Remington and Orella) across Sand Creek (Figs. 4 and 5). Here, again,

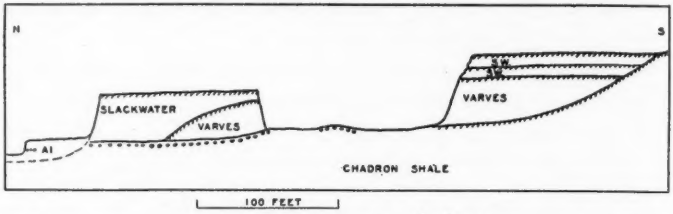


FIG. 5. Diagrammatic cross-section of Sand Creek Valley east of Highway No. 2 bridge. Shading represents soil.

the sequence of events was erosion, deposition, erosion, and deposition, with the varved sediments being one member of the series. The section along the south valley side is as follows:

	Feet
Soil, black, calcareous	3
Silt, stratified slackwater	4
Silt and soil alternating	4
Silt, stratified slackwater	3½
Soil, black	1
Silt, stratified slackwater	5
Varved silt and clay	7½
Soil, charcoal	1
Silt, hard	2½
Silt, invertebrates	½
Gravel, silt	1+

The altitude of the top of the varved sediments was measured as 3,665 AT., which is probably correct to within 10 feet, for the reading was the same on the Paulin altimeter on two different days. The measurements of the varves are shown on Fig. 7.

Big Cottonwood Creek. On the north side of Big Cottonwood Creek, two miles northeast of Whitney and a quarter of a mile above the railroad bridge (SW. ¼, NW. ¼, Section 28, T. 33 N., R. 50 W., Dawes County), the

high, vertical, undercut bank shows 10 feet of varved sediments lying on Pierre shale and overlain by 10 to 15 feet of slackwater silt. While some of the winter layers are good clean-cut ones, many of them are mottled and turbulent in detail, as though they were originally poorly formed or have been materially disturbed since deposition. The latter seems to be more probable. No measurements of the varves were made at this location, since the bank was almost inaccessible at the time of the visit and it would have taken several days of digging to get reliable measurements if such were present. However, from what was seen of the varves, they seem to be typical of the varvd sediments seen elsewhere in the White River drainage. The top of the varves was measured by aneroid as 3,350 feet above sea level.

Pineridge, South Dakota. Two miles west of Pineridge, South Dakota, in a road cut on the side of a small tributary to the White River, eight feet of silt lies on 3½ feet of varved sediments with a pebble band at their base lying on black soil on silt. Although the varves are well formed, there are only eight winter layers, so no measurement was made.

Interior, South Dakota. Nine miles east of Interior, South Dakota, on the road to Weta, and 100 feet south of the highway bridge across the small stream, eight feet of varved sediments below ten feet of slackwater sands and silts are seen on the east side of the small stream. The elevation of the Chicago, Milwaukee and St. Paul Railroad at Interior is 2,381 feet above sea level. The top of the varves, therefore, is very close to 2,340 feet above sea level. The base of the varved sediments is not exposed. There is a soil zone and erosional unconformity between the varved sediments and the overlying slackwater ones. From the fact that the stratification of the slackwater deposits, where they lie against the eroded surface of the varves and gravel, is perfectly horizontal (Fig. 6a), it would appear as though they had been deposited in standing or exceedingly quiet water. Measurements of the varves were made and appear in Fig. 7.

FIG. 6a. Slackwater beds on soil-covered gravel nine miles east of Interior.

Chamberlain, South Dakota. The highway cut one mile north of Chamberlain, South Dakota, in the Missouri valley, ten miles north of the mouth of White River, exposes a section of a terrace in which five feet of varved sediments lie on six feet of gravel and below five feet of stratified sand (Fig. 6b). The elevation of the top of the

FIG. 6b. Varves one mile north of Chamberlain.

terrace is about 1,470 feet above sea level. The summer layers of the varves contain some sand, and in three cases, layers one quarter to one half an inch thick of very fine gravel. The winter layers, however, are composed of the typical dark gray, greasy, fatty clay. Measurements of the varves were made and appear in Fig. 7.

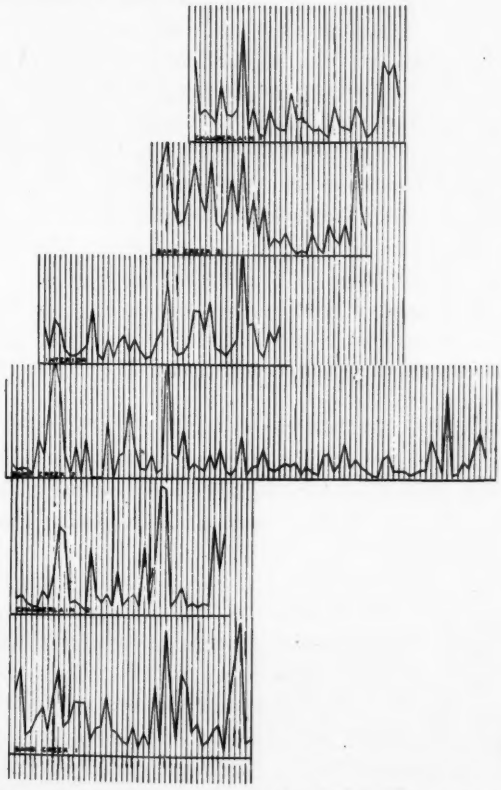


FIG. 7. Graph of the varves in White River Valley. Scale × ½.
Sand Creek 1 = East side butte east of Sand Creek bridge.
Sand Creek 2 = One mile east of Everson's house.
Sand Creek 3 = South bank, east of Sand Creek bridge.
Chamberlain 1 = One mile north of Chamberlain.
Chamberlain 2 = 250 feet north of Chamberlain 1.
Interior = Nine miles east of Interior.

Another exposure, 250 feet to the north on the same side of the road and in the same terrace, shows a similar thickness of varves. In this place, however, the base of the varved deposit is not exposed. These varves were measured also and appear in Fig. 7.

Mouth of White River. A terrace on Pierre shale rises to 175 feet above the flood plain of the White River, two miles above its junction with the Missouri. This terrace (1,500 feet altitude) is capped by six feet of medium coarse erratic gravel, over which are 9½ feet of varved sediments under ten feet of slackwater silts. Only seven varves are present, for the summer layers are exceptionally thick. The summer layers contain some sand and even fine gravel. The winter layers, however, are very good in most cases, being composed of the typical greasy clay. Although the varves were measured, there were so few of them and they were so exceptionally thick that for correlation purposes they seem to have little value and have not been plotted.

CHARACTER OF THE VARVES

There are three main types of varves: those in which there is a gradual transition from coarse material at the bottom to fine at the top, known as *diatactic*:[2] those with both coarse and fine material throughout the varve, known as *symminct;* and those in which there is "no apparent upward decrease in coarseness but the winter layer shows sharp lower as well as upper limitation."[3] As far as the study of the varves of the White River Valley has gone, only the third type has been noted, in which both the upper and lower limits of the winter layers are sharply demarked. The summer layers are predominantly composed of fine buff silt, but there are occasional thin layers of very fine sand. The winter layers are composed of dark-colored, greasy, smooth, fatty clay, that reveals no grit even between the teeth. There are two

[2] M. Sauramo, *Comm. Geol. de Finlande*, No. 60, p. 78, 1923.

[3] E. Antevs, Geol. Surv. Canada, Dept. Mines, Mem. 146, p. 13, 1925.

types of exceptional winter layers. One type is multiple, having a thin parting of silt, or in several cases, two thin partings to make a "twin" or a "triplet" winter layer. These partings are so very thin, 1/32 or 1/16 inch, that they seem to represent a thaw during the winter rather than the whole summer layer of another varve. The second exceptional type of winter layer consists of fatty clay with small masses of silt in turbulent arrangement scattered through it so as to give the layer a mottled appearance. Such winter layers seem to have been produced by a disturbance in some way, either during or after deposition.

The large variations in the thicknesses of the varves, as seen in Fig. 7, show that they were formed under somewhat different conditions from those in Sweden, New England or eastern Canada. This would be expected, since in the latter cases the dominant source of sediment was the glacier, and transportation was characteristically away from the ice-front, through the lake, to an outlet somewhere on the far side. On the other hand, the lake in White River Valley was long and narrow, with the dam at its lower or eastern end. As a result, it is believed that probably some, if not much, of the sediment making up the varves was contributed to the lake by wash within its own drainage basin.

Correlation of the Varves

The varves, as measured in the field, have been plotted to scale in Fig. 7. No adjustments have been made. There is a chance in measuring the varves for error in judgment in considering a twinned winter layer as part of one rather than two varves. Antevs, in his study of the varve chronology in eastern North America, had so many sections that he was able to adjust those that showed some discrepancies and to discard as abnormal those sections that fit very badly. It may be possible to do the same thing here when more exposures have been measured in the White River basin.

Keeping these various considerations in mind, there still seems to be more than coincidence in the correlation between the graphs. There are many striking similarities, even while there are obvious discrepancies at many points. On the basis of these graphs, it would appear that the varves are contemporaneous; but whether or not the curves establish contemporaneity, the deduction remains that the varved sediments were deposited in a lake and that in all probability this lake was formed by an ice dam at the lower end of White River, where Wisconsin drift reaches the Missouri valley.

Old Red Lake. Todd[4,5] described the glaciation of the region near the mouth of the White River, and he found that in pre-Wisconsin time the White River flowed eastward to the site of the present James River. The Wisconsin ice advanced westward and dammed the lower part of this old White River to form a lake, to which he gave the name of Old Red Lake. Its outlet was around the ice edge and across the divide west of the Bijou Hills. Todd did not specify the altitude of the surface of the lake, but at the time he considered that the boulders west of the Missouri, up to 1,800 feet elevation, were ice-rafted to their present situation on the surface of the lake. He says that "the outlet of Old Red Lake through the Bijou Hills and around the ice at Pratt Creek probably soon cut down to the 350-foot terrace level (1,685 feet altitude) by the deepening of the channel west of the Bijous."[6] His maps (Plate XV (1899) and Fig. 3 (1902)) show the lake as a small one extending only a few miles up the White River Valley. In a later paper[7] he does not mention the lake and attributes the outlying boulders to an earlier glaciation. The present Missouri River is believed to date from Wisconsin time.

The history of the glaciation of the region around Chamberlain seems to need further study and accurate

[4] J. E. Todd, *Bull.* 158, U. S. Geol. Surv., pp. 32–53, and Plate XV, 1899.
[5] J. E. Todd, *Bull. Geol. Soc. Amer.*, 13: 27–40, 1902.
[6] J. E. Todd, *op. cit.*, p. 53, 1899.
[7] J. E. Todd, SCIENCE, n. s. 39: 263, 1914.

mapping, for till was found on the upland at several places on the west side of the Missouri valley. Such detailed study would reveal whether or not this outlying till was deposited by an extension of the Wisconsin ice sheet or by an older ice sheet, such as the Iowan, Illinoian or Kansan. If the latter were the case, the boulders scattered west of the Missouri might prove to be remnants of a much eroded till sheet instead of ice-rafted material of late Wisconsin age. But with the exception of some details, Todd seems to have correctly expounded the evidence for an ice-dammed lake. The current investigation, however, suggests that this lake extended up the valley of the White River to the neighborhood of Crawford, Nebraska. Leverett[8] described a moraine of the Dakota lobe lying a little beyond the Altimont Moraine and known as the Bemis Moraine. It was the ice at this stand which dammed the lake at the climax of the last or Mankato[9] advance of the Wisconsin glaciation.

Origin of the Varved Sediments

Three possibilities for the origin of the varves might be considered for completeness of the discussion:

(1) The varves may conceivably have been deposited in local lakes in the valley of White River. Such lakes might have been formed as ox-bows or bayous during the normal history of the river or formed by landslides or eolian action during a special episode of the river's history. The presence of the varves in the small tributary valleys near the headwaters of the river renders its applicability very doubtful in regard to the former. And as to the latter, the shape of the valley, particularly at its lower end, seems to preclude landsliding, and a barrier of sand dunes would be partly left in the valley. Furthermore, it is doubtful that varves would accumulate in a lake or lakes thus formed unless the climate was a glacial one, in which case suggestion (3) would be more feasible.

[8] Frank Leverett, U. S. Geol. Surv., *Prof. Paper* 161, p. 67, 1932.

[9] F. T. Thwaites, "Outline of Glacial Geology," p. 78, 1934.

(2) The varves may have accumulated in a lake formed by diastrophism of the region through which the valley passes. There is some evidence of movement along older structural lines in the eastern part of the White River basin. The eastern third of the valley is narrower also, and more deeply trenched than it is in the middle and upper course. But the presence of varves in the Missouri valley at Chamberlain would make necessary the diastrophic barrier across the Missouri in the vicinity of the drift border. The diastrophic hypothesis lacks the support of convincing evidence at the present state of knowledge. It is, also, not known that varves would form in such a non-glacial lake.

(3) The varves may have been deposited in Old Red Lake, which according to Todd was formed by the ice of the late Wisconsin glacier damming the White River.

This third hypothesis seems to be supported by more facts than the others. If it be the correct explanation of the phenomena, the varved sediments are then closely dated in relation to Pleistocene glaciation. They become a good horizon for dating later Pleistocene events in the White River Valley. A relative rise of the western region of more than 2,000 feet since the varves were deposited is indicated, since the varves are now found at 1,500 feet altitude near the mouth of the river, 2,340 feet near Interior and 3,665 feet near Crawford. Physiographic studies have long shown a rise in the western Great Plains, though some have considered the rejuvenation as possibly climatic. We have proof not only of a rise but also of the date and the amount of rise if the hypothesis of a glacial lake be valid.

HUMAN OCCUPANCY

A great many Yuma points have been picked up in Sand Creek Valley by Nebraska Museum parties[10] as well as local collectors in the past few years. Artifacts were found *in situ* in 1935 in the pre-varve soil zones, notably Soil B, Fig. 3. Several typical Yuma artifacts were

[10] This material is in the Nebraska State Museum.

FIG. 8. Fire pit below twin soil zone.

FIG. 9. Deeply buried fire pit.

found in a nearby locality in a soil zone which seems to correspond to Soil B. Fossil mammal and bird bones were discovered in these same soil zones. In many places, the bones were in a broken and burned condition. Also approximately 150 fire pits were found within the area (Fig. 8). Some of these pits were buried as deeply as 25 feet (Fig. 9). The fire pits, which were filled with much charcoal and burned stones, had been dug to 1½ to 2 feet below the original habitation surface. Their rims appear to be at the level of the lower member of the twin soil zone A of Fig. 3.

SUMMARY

There are varve sediments in the White River Valley, as far west as the vicinity of Crawford. It is a possibility that the varved sediments may have been deposited in such an ice-dammed lake, since the White River was dammed at its eastern end by ice of the late Wisconsin glacial invasion. A rise of the western part of the basin, with respect to the eastern part, of 2,000 feet in post-Wisconsin time, has taken place if this should prove to be the case. Furthermore, the relationships of the soil zones, containing hearth-pits and artifacts, suggest that the latter are older than the varves and hence are of Pleistocene age. More intensive investigation of the sites and the Pleistocene history of the region is planned for the coming seasons.

ACKNOWLEDGMENTS

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RECENT STUDIES OF EARLY MAN IN THE SOUTHWESTERN PART OF THE UNITED STATES

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THE opportunities for the study of early man are particularly promising in the southwestern part of the United States. From the time of the initiation of the present topography, drainage streams originating in the Rocky Mountains have built successive terraces as they lowered their valleys into the plains region across which they flowed. Influenced possibly by the glacial period, but beyond the limits of destruction by glacial ice, the stream terraces in parts of the region attained a wonderful development and have been well preserved. If man lived in this region in early time, he should have left some trace of his presence in these stream deposits, either as skeletal remains or as artifacts. Man early acquired the art of working stone into implements. These stone implements, capable of withstanding disintegration for a long period of time, must occasionally have become included in such accumulating stream deposits. These deposits vary in age from the relatively late terraces, barely above the present high water stage, to the high terraces much above the present stream level. Vertebrate fossils are found in many of these terraces.

The present paper is concerned chiefly with occurrence of artifacts in a low, and hence relatively late, terrace in central Texas. The principal locality is near the town of Round Rock in Williamson County. The discovery of artifacts in the terrace at this locality was made by Professor James E. Pearce, of the Department of Anthropology of the University of Texas, and the archeological material obtained will be described by him. This paper, accordingly, is confined to the geologic relations of the terrace deposits.

The small stream which forms the terrace, known as Brushy Creek, rises in the highlands a few miles to the west and flows in an easterly direction, being a part of the Brazos River drainage system. The bed-rock formations on which the stream deposits rest are of Cretaceous age and consist of limestones and shales. The Cretaceous formations are here broken by faulting as a result of which perennial springs arise in the bed of the stream, forming an unfailing water supply. These conditions are indicated in the accompanying sketch map or plan of the locality (Fig. 1).

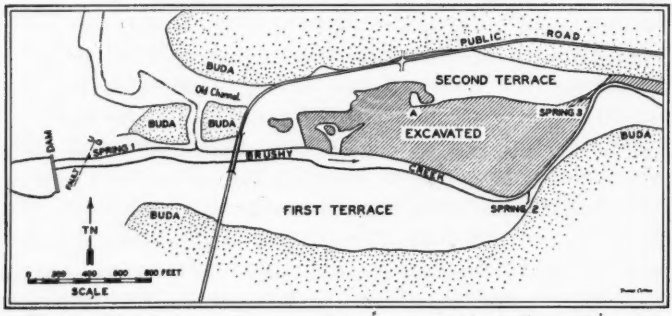

FIG. 1. Sketch map of terrace deposits near Round Rock, Texas. A, principal locality at which artifacts are found.

The Cretaceous formations exposed at this locality in order of age are the Georgetown limestone, Del Rio clay and Buda limestone, the first named being the oldest. The dam indicated on the sketch rests on the Georgetown limestone. A fault trending northeast, downthrown to the southeast, passes just east of the dam. East of the fault the Del Rio clay forms the bed-rock underlying the terrace deposits. The Buda limestone is present in the hills at either side of the stream, but, except for two small remnants west of the public road, has been removed by erosion in the stream valley. The Cretaceous formations just east of the line of faulting are slightly folded, the fold, trending northeast-southwest, being incident probably to the faulting. The stream cut across and into this fold so that the bed-rock of the valley was originally

a window of the Del Rio formation exposed through the Buda. A rim of Buda still almost encircles the valley, forming an escarpment on the north, south and east, except a notch on the east through which the stream flows. At the west, or upstream, end of the valley are remnants of Buda as indicated in the sketch.

Within the stream at the present time are two well-developed terraces. The lower and younger of these terraces, occupying approximately the southern half of the valley, rises above the present stream level 10 to 13 feet and is submerged at flood stage of the stream. Bed-rock (Del Rio clay) under the low terrace is at or near present stream level. A second terrace in which the artifacts are found, occupying at this place most of the northern part of the valley, rises above the present stream level 20 or 25 feet. Bed-rock under this terrace is from 1 foot to 8 feet above present low water level in the stream. Approximately one half of this second terrace has been excavated and removed, the gravel being used in road building. A section of the terrace deposits containing the artifacts at locality "A" of the sketch map is as follows:

	Thickness in feet
Heavy rock and gravel at top of exposure; contains artifacts and hearths	6 to 8
Silt stratum; contains snail shells and some gravel	7.5 to 8
Stream-laid clean gravel, resting on bed rock	3.5 to 7
Del Rio clay, bed rock, at bottom of exposure.	

The stream-laid gravel at the base of the section and the overlying silt stratum both contain artifacts, indicating the presence of man in this immediate region when this older part of the terrace was being accumulated. The overlying stratum of coarse rock and pebble indicates a pronounced change in depositional conditions. Some of the large rocks of this stratum are a foot or more in thickness and weigh several hundred pounds. This bar of coarse rock and gravel was accumulated when the stream was working against the north, or left, side of the valley,

forming a bluff capped by Buda limestone, from the débris of which the bar was chiefly formed.

. At high flood stage of the stream, this terrace is submerged or nearly so. However, no flood in this stream at the present time could possibly lift these large rocks to such high level in the terrace. This stratum of boulders and coarse gravel was, therefore, deposited under conditions differing from those of the present time. That the deposits were stream-laid in strong currents is shown by the assortment of material and particularly by the position assumed by the flat rocks. Artifacts are present

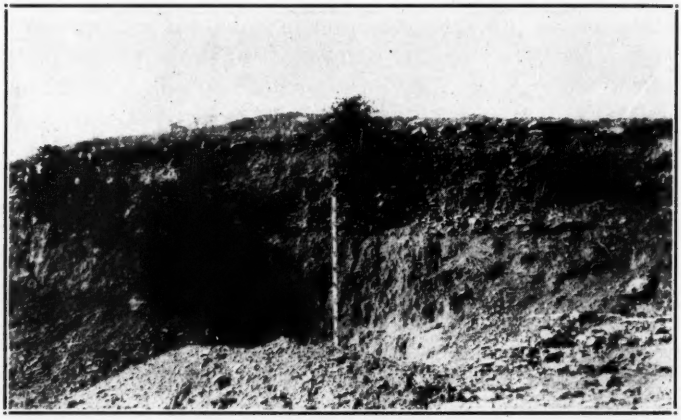

FIG. 2. View of face of terrace at locality "A" of Fig. 1. Coarse rock and gravel stratum at the top of the exposure containing artifacts, below which is silt stratum, which also contains artifacts. Gravel stratum at base of terrace not seen in this view. The rod rests on bed rock at the bottom of the terrace deposits.

in this stratum and, in addition, there are well-preserved hearths, showing that man was living on the terrace, or rock bar, at the time it was being built by successive floods. In the accompanying photograph (Fig. 2) the coarse rock and gravel stratum may be seen. The 14-foot rod rests on the bed-rock, the lower part of the section not being visible in this view.

FIG. 3. Face of terrace from locality "A" of Fig. 1 to spring No. 3. Terrace deposits of the foreground removed for road-building.

Fig. 3 is a view taken from approximately the same place as Fig. 2, but with the camera directed downstream. The part of the terrace seen in this view is that along the line from locality "A" on the map eastward to spring No. 3. Artifacts in the terrace are most abundant at and near locality "A" but are present throughout the terrace.

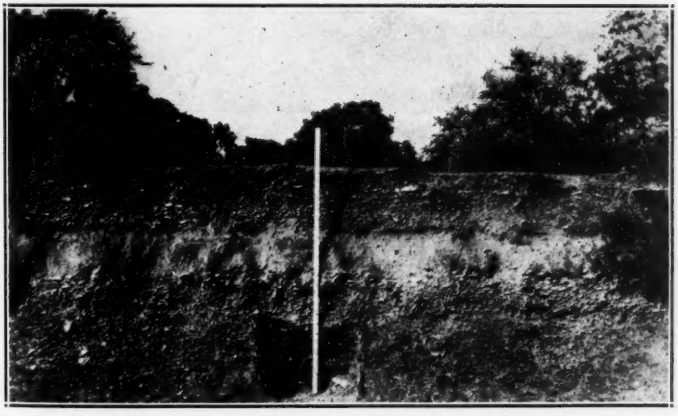

FIG. 4. Face of terrace near spring No. 3. Coarse rock and gravel stratum thin. The rod here does not rest on bed-rock.

Fig. 4 is a view of the face of the terrace near spring No. 3.

The artifacts in the terrace deposits are not confined to this particular locality. Fig. 5 is a view of the face of a terrace of about the same height, 25 feet above low water level, 2 miles farther downstream. The uppermost stratum of large rock and gravel is present, although of reduced thickness. These large rocks, 25 feet above present stream level, were plainly deposited under conditions differing from those of the present time. Artifacts occur in this terrace. Worked flints were collected at localities indicated in 1 and 2 in the photograph. The bed-rock at this locality is the Austin formation.

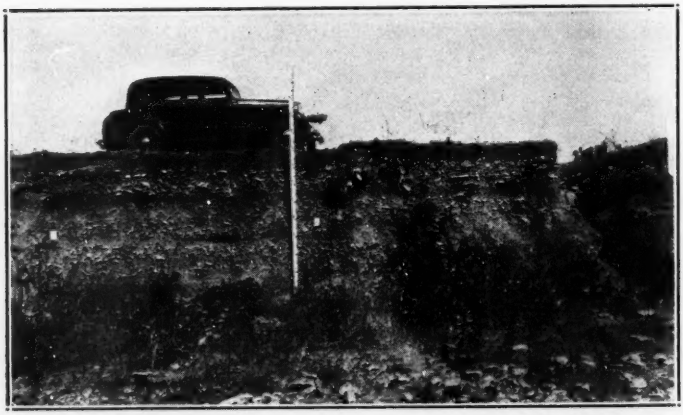

FIG. 5. Terrace containing artifacts on Brushy Creek, two miles east of Round Rock. Coarse rock and gravel stratum at top underlain by silt, gravel and rock deposits containing artifacts.

Terrace deposits of approximately the same age have yielded artifacts at several other localities on other streams in this part of the state. Occurrence of artifacts in higher and much older terraces has likewise been reported. Some of these localities, such as Frederick, Oklahoma, await further exploration, particularly to prove the place of the artifacts in the section.[1]

[1] Citation of literature and description of geologic conditions at Frederick are given in *Bull. Geol. Soc. Amer.*, 43: 783–796, 1932.

History of Deposition of Sediments

A part at least of the history of deposition in the terrace containing the artifacts at Round Rock can be determined. The gravel at the base of the section and the overlying silt stratum, making a total of 11 or 12 feet, represent normal or usual accumulation of terrace deposits in and at the side of a small stream. The overlying stratum, containing rock boulders and coarse gravel, can be satisfactorily accounted for apparently only by assuming that subsequent to the formation of the gravel and silt deposits the valley of the stream bed filled by aggrading processes so that the stream came to flow on its own fill. Under those conditions the rock bars which make up the top stratum of coarse rock of the terrace deposits were formed. Since the formation of these rock bars, the valley has been reexcavated to its present level.

The amount of water carried by the stream may or may not have been greater at the time this stratum of large rock and gravel was formed. Volume of water alone, however, is not sufficient to account for the accumulation of large rocks at this level. On the other hand, assuming fill of the valley to such an extent as to allow the stream to flow at the rock bar level, this rock stratum could have been formed by the stream with the present volume of flow at flood stage. The largest of the rocks came from the Buda limestone which outcrops near by and hence were not carried far. The large rocks found at a similar level in the terrace 2 miles downstream are from the Austin chalk, which is there the country rock formation. At each locality these rock bars were built on a preexisting stream deposit, thus aggrading the stream valley.

Age of the Round Rock Terrace

The age of the Round Rock terrace is undetermined. No vertebrate fossils have been found, and the snails and clams obtained afford little or no help in determining age. The position of the terrace, 20 to 25 feet above present stream level, indicates an age relatively late as compared

to the other and higher terraces. On the other hand, one can picture certain events that must have occurred since these deposits were formed; indicating a considerable lapse of time. First of all, the stream valley was filled to a depth of 11 or 12 feet. This fill in the stream valley could not have been local or confined to this valley, but must have been common to the streams of this part of the state. The presence of faulting in the bed-rock formations might lead one to suppose that aggrading of the stream valley was possibly caused by change in level due to faulting. This, however, can not be true, as the terrace deposit extends directly across the fault. It is thus shown that faulting occurred previous to the time that this terrace was formed. Following aggrading of the valley until the terrace deposit reached its present height came reexcavation by which the stream cut to, and somewhat below, its former level. After reaching the present level, the stream formed the more recent or first terrace shown on the map.

Some shifting of the position of the stream is indicated. At the time the rock and gravel bar was being accumulated at locality "A" and elsewhere on the second terrace, the tributary stream, and perhaps Brushy Creek itself, flowed in a now abandoned channel, marked "old channel" on the map. The cut by the tributary stream through the Buda limestone just above the bridge has been made recently, as proven by the narrow channel and steep sides, and is a feature of the reexcavation of the valley. At the time of the maximum aggrading, the Buda limestone remnant was completely engulfed in valley fill. When Brushy Creek took its present position, the tributary became superimposed on this block of limestone and, as excavation of the valley proceeded, cut its way through the limestone, forming the narrow channel through which it now flows. Man, as the evidence shows, inhabited the region during the entire time of fill and reexcavation of the valley, but what this time, geologically speaking, represents, one can not say until evidence from physio-

graphic changes can be supported by evidence from fossils.

MOLLUSKS ASSOCIATED WITH EARLY MAN IN THE SOUTHWEST

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THE importance of mollusks as indicators of the climate of the Pleistocene has been pointed out on frequent occasions. While the writer's studies on this subject have largely been concerned with the marine shells of the period, he has recently had the opportunity of examining three small collections from the Pleistocene of the Southwest. Two of the localities are of special significance because they have yielded artifacts of the Folsom variety, thus suggesting the presence of early man in America. These localities have been discussed in the present symposium.[1]

Mollusks from the lake beds at Clovis, New Mexico, have already been identified by Dr. H. A. Pilsbry and are listed by Howard,[2] who first reported the traces of early man from this locality. A set of mollusks from the same beds was recently received from Mr. J. R. Whiteman, of Clovis. The two sets are practically identical, although Mr. Whiteman's set included two land species—*Succinea retusa* Lea and *Discus cronkhitei anthonyi* (Pilsbry). The fresh-water snail *Lymnaea palustris nuttaliana* Lea from the Clovis beds is at present living in the higher mountains of New Mexico and Colorado and is rather generally distributed throughout the northern Rockies as well as the whole of the northern part of the United States and Canada. According to Dr. Pilsbry, "The presence of this species fossil in southeastern New Mexico, in a

[1] See addresses by Dr. Edgar B. Howard and Dr. Frank H. H. Roberts, pp. 314 and 337.

[2] Edgar B. Howard, *The Museum Journal*, Univ. Museum, Univ. of Penn., 24: 89–90, 1934.

region near the junction of the upper and lower Austral zones, indicates widely different climatic conditions from those now prevailing there, and leads to the conclusion that the deposits date from Glacial (Pleistocene) time." Unusually large shells of *Helisoma trivolvis* (Say) and *H. anceps* (Menke) confirm this conclusion. The other species are less significant—*Gyraulus parvus* (Say), *Physa* sp. (young), *Sphaerium* near *modestum* Prime and *Pisidium* sp.

Quaternary lake beds near Keet Seel, in the Navajo Indian Reservation in northeastern Arizona, yielded a fauna somewhat resembling that from Clovis. The material was obtained from Dr. Ernst Antevs, research associate of the Carnegie Institution, and Mr. Edwin D. McKee, of the Grand Canyon National Park. It is evident that the deposits represent a succession of different ages, and a more detailed stratigraphic study of the material is planned. Seven species were represented. Two of the northern elements of the Clovis fauna were present, namely, *Lymnaea palustris nuttaliana* Lea and *Helisoma trivolvis* (Say). In addition, *Lymnaea stagnalis jugularis* Say [= *appressa* (Say)] was fairly frequent. Like *nuttaliana* this species is characteristic of the northern part of the United States and Canada, and has not been reported alive as far south as Arizona, although it is known from Colorado and Utah. It is known as a Pleistocene fossil from White Cone Butte, also in the Navajo country of Arizona,[3] Lake Bonneville and Sevier Desert, Utah, and at the Humboldt sink at the Lahontan area in Nevada.[4]

The other species from Keet Seel are of wide distribution and are at present living in the region. They are *Succinea retusa* Lea, *Gyraulus parvus* (Say), *Physa heterostropha* (Say)—in broad sense—and *Pisidium* sp.

Nine species of land mollusks were identified from the Lindenmeier Site near Fort Collins, Colorado. Folsom

[3] A. B. Reagan, *Trans.* Kansas Acad. Sci., 35: 253–259, 1932.

[4] Frank C. Baker, *Chicago Acad. Sci. Special Publ.*, 3: 146–147, 1911.

points have been discovered here and the locality has been discussed by Roberts[5] in this symposium.

Two of the nine species are southern forms and are some two hundred miles north of their present recorded northern limit. *Gastrocopta ashmuni* (Sterki) is not known alive north of Grand Canyon, Arizona, and southern and central New Mexico. *Pupilla sonorana* (Sterki) has its present northern limit at Moro County, New Mexico. The other species have no special significance and can be found living in the region to-day. They are *Gastrocopta armifera* Say, *Pupilla muscarum* (Linne), *Pupoides inornatus* Vanatta, *Vertigo* sp. (broken), *Valonia gracilicostata* Reinh., *Succinea avara* Say and *Zonitoides arborea* Say.

It is not proposed at this time to attempt to date the deposits by means of these small collections of mollusks. Such an attempt would require more extensive collections, both of fossil and recent species of the region. We merely call attention to the presence of the mollusks in these deposits—in two cases associated with early human cultures—and to show that a slightly more humid and cooler climate is suggested from the Clovis and Keet Seel deposits, while a somewhat warmer climate is perhaps indicated from the deposits near Fort Collins, Colorado. It is hoped that further collecting will shed more light on this subject.

[5] Frank H. H. Roberts, p. 338.

THE NON-IDENTITY OF THE NEUROHUMORS FOR THE MELANOPHORES AND THE XANTHOPHORES OF FUNDULUS[1]

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IT has been shown that the reactions of the xanthophores (yellow pigment cells) in *Fundulus heteroclitus* are independent of the responses of the melanophores-black pigment cells (Connolly, 1925; Fries, 1931). For example, both the xanthophores and the melanophores are contracted in a fish which has been kept for some time in an illuminated white vessel, and both are expanded in one kept in an illuminated black vessel. In an animal adapted to a blue background, however, the melanophores are mainly expanded and the xanthophores contracted, while on a yellow background, the xanthophores are expanded and the melanophores are contracted. Thus this independent behavior of the yellow and black pigment cells to yellow and blue backgrounds led Fries to conclude that the two types of chromatophores were controlled by separate sets of neurons.

In the following year, Parker (1932) formulated the neurohumoral hypothesis for the control of chromatophores on the basis of the responses of denervated melanophores. Such responses were first clearly described by Fries (1931), who declared that they must be governed by humoral substances. Mills (1932), who studied in detail the same responses, concluded also that humoral factors were responsible for the activity of denervated melanophores and stated further that these humoral substances were secretions from intact nerve terminals surrounding

[1] These experiments were performed at the Marine Biological Laboratory, Woods Hole, Massachusetts, during the summers of 1934 and 1935. For the privilege of working at the laboratory in 1935, I am especially indebted to its director, Dr. M. H. Jacobs.

the denervated sector of the tail. The evidence for this novel interpretation of nervous activity came chiefly from the reactions of denervated caudal melanophores (Mills, 1932; Parker, 1934a, 1935b). Nevertheless, the corollaries of the hypothesis demand that this notion shall apply to other normally innervated chromatophores. Indeed, Parker (1932) writes " . . . in Fundulus, with its two independent classes of chromatophores, melanophores and xanthophores, it is necessary to assume four humoral substances, which, . . . might be called melanoexpantin, melanocontractin, xanthoexpantin, and xanthocontractin" (page 48). This report will present evidence showing the validity of this assumption.

The evidence was obtained by studying the responses of denervated chromatophores to variously colored environments, and is significant only in proportion to the correctness of the diagnosis (neurohumoral activity) of the slow, denervated melanophore responses to white and black backgrounds. As an illustration of such responses, the experiments of Mills (1932) and of Parker (1934a), which can be repeated at will, may be cited. Several rays of a killifish tail are severed by a transverse incision through the tail tissues. This operation results in the formation of a dark band, distal to the incision and extending to the tip of the tail. In this dark band, one finds melanophores whose pigment is fully dispersed. These melanophores have now no nervous connections with the central nervous system. If the fish, whose tail has thus been treated, is left to reside in a constantly illuminated white dish, the dark band fades slowly from its edges inwardly, until it becomes entirely pale. This bleaching requires as much as several days for completion. If the fish is now placed in an illuminated black dish, the same process occurs, but in reverse order. The band, made light by prolonged subjection to a white environment, becomes slowly dark. Thus, these slow reactions of the denervated caudal melanophores to backgrounds consti-

tuted primarily the basis of the neurohumoral theory, although subsequently evidence from other sources has been accumulated (Parker, 1935a). Fries previously showed that the xanthophores behaved somewhat similarly. He sometimes found in the transfer of a killifish from a yellow background, where both the innervated and the denervated xanthophores were expanded, to a white vessel that the innervated xanthophores contracted quickly, as is their custom, and that the denervated xanthophores also contracted, but four hours later. In short, neurohumoral responses of denervated tail melanophores and xanthophores have been shown to occur separately to a greater or lesser extent. To show that denervated melanophores and xanthophores respond independently of each other, as do the innervated melanophores and xanthophores, is the final test of the application of the neurohumoral assumptions, and the subject of this paper.

The experiments were performed on the mayfish, *Fundulus majalis* Walb., because its xanthophores are more distinct than those of *F. heteroclitus*. The caudal fin of *F. majalis* contains numerous large xanthophores and few melanophores. Their reactions to yellow, white, black and blue backgrounds, according to Fries, are identical to those shown by the chromatophores of the killifish. When a transverse cut is made through two or three rays of the fin, a deep yellow band extending from the cut to the periphery of the tail is formed. Microscopic examination discloses that the melanophores and the xanthophores in the yellow area have their pigment fully dispersed. The band appears yellow because the yellow pigment cells far outstrip the black in numbers. In females of *F. majalis*, however, where there are more melanophores per xanthophore, the band appears yellow, tinged with black. Two sets of fishes in whose tails such bands were induced were set aside, one set in white dishes and another in black dishes, all being illuminated night and day by two seventy-five watt electric lamps.

At the end of the eighth day, the white-adapted fishes had lost the yellow color of their caudal bands, which were now indistinguishable from the tint of the animal as a whole. Those in the black vessel were uniformly dark and, in order to test the condition of their bands, they were white-adapted for ten minutes. The dark animals turned pale, excepting for the caudal bands, which remained darkly yellow just as if they had been recently formed. Microscopic examination of both sets of fishes disclosed that the denervated areas of the white-adapted animals contained melanophores and xanthophores in a contracted condition; whereas the yellow and black pigments in the sectors of the black-adapted fishes were both well dispersed.

The white-adapted animals were now distributed equally among blue, yellow and black dishes; and the black-adapted fishes were equally distributed among white, yellow and blue dishes. Two days later the denervated sectors were examined microscopically. Then, the fishes on blue were divided among black, yellow and white environments; those on yellow among white, black and blue vessels; the black among white, yellow and blue dishes, etc. Thus, animals adapted to one background were transferred to another background in all possible combinations. The conditions of the melanophores and the xanthophores, both innervated and denervated, were examined before and after the change, 2 to 3 days being allowed between observations. The data are recorded in Table I.

The results show that the denervated xanthophores attain the same state in the distribution of their pigment as the innervated xanthophores, and do so independently of the condition of their contrasting neighbors, the denervated melanophores. When the innervated yellow cells are contracted, as on a blue background, the denervated yellow cells also reach this condition, although both the innervated and the denervated melanophores are mainly

TABLE I

RESPONSES OF INNERVATED AND DENERVATED CAUDAL CHROMATOPHORES TO VARIOUS BACKGROUNDS—FUNDULUS MAJALIS

Animals adapted to the following backgrounds:	Conditions of the chromatophores				Animals changed to the following backgrounds:	Conditions of the chromatophores			
	Innervated		Denervated			Innervated		Denervated	
	Mel.	Xan.	Mel.	Xan.		Mel.	Xan.	Mel.	Xan.
1. White	C	C	C	C	Yellow	C	mE	mC	E
2. White	C	C	C	C	Black	E	E	E	E
3. White	C	C	C	C	Blue	mE	C	mE	C
4. Black	E	E	E	E	Yellow	mC	E	mC	E
5. Black	E	E	E	E	Blue	mE	C	mE	C
6. Black	E	E	E	E	White	C	C	C	C
7. Blue	mE	C	mE	C	Black	E	E	E	E
8. Blue	E	C	E	C	White	C	C	C	C
9. Blue	mE	C	mE	C	Yellow	C	mE	mC	E
10. Yellow	C	mE	C	E	White	C	C	C	C
11. Yellow	mC	E	mC	E	Blue	mE	C	mE	C
12. Yellow	C	E	C	E	Black	E	E	E	E

Explanation of symbols:
Mel.—melanophores
E—fully expanded
Xan.—xanthophores
mC—mainly contracted
C—fully contracted
mE—mainly expanded

expanded. The same state but in reverse order is found in yellow-adapted fishes. The reactions, then, of the denervated melanophores and xanthophores in relation to the responses of the innervated melanophores and xanthophores to various backgrounds are precisely what has been predicted for them by Parker on the basis of neurohumoralism.

The contingency that the reactions of the denervated chromatophores might be due to reestablished nervous connections was discounted by testing for regeneration of nervous elements to the band by the methods devised by Parker and Porter (1933) and Abramowitz (1935). A remaining possibility—that blood-soluble materials, which might be normally elaborated in the bodies of these fishes and which are effective in producing the same responses already recorded—was defeated by repeating Parker's (1934b) experiment of washing out the tint of a dark denervated band by means of adrenalin. Fishes, the melanophores and xanthophores of whose denervated bands were both maximally expanded, were injected with 0.1 to 0.2 cc of adrenalin chloride (1:1000). Within eight

minutes, the denervated melanophores and xanthophores as well as the innervated melanophores and xanthophores were entirely contracted. The reverse experiment was performed by injecting 0.3 to 0.4 cc obstetrical pituitrin (Parke, Davis and Co.) which Kleinholz (1935) has already shown to be capable of dispersing denervated caudal melanophore pigment in *F. heteroclitus*. Injection of this substance into white-adapted fishes, whose innervated and denervated melanophores and xanthophores were maximally contracted, was followed after ten minutes by a partial expansion of the innervated xanthophores, a full expansion of the denervated xanthophores, a stellation of the denervated melanophores and by no change in the innervated melanophores. Such immediate responses of the denervated chromatophores to blood-soluble materials (adrenalin, pituitrin) are evidence, according to Parker (1934b), that the factors which evoke the same responses normally seen in fishes when transferred from one background to another are not carried in the blood stream. They are therefore, with reason, believed to be nervous in origin.

The likelihood that blood-soluble substances, especially pituitary hormones, may be normal factors in the change, for example, of a fish from a white to a black background has not yet been discredited. The rôle of the pituitary in the denervated chromatophore responses to black surroundings can be evaluated only when such neurohumoral experiments are repeated in hypophysectomized Fundulus. Until this is accomplished, the conclusion is tentatively advanced that denervated xanthophores are activated by neurohumoral materials and that such materials must be distinct from those which activate the denervated melanophores.

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LINKAGE RELATIONS OF CREST, DOMINANT WHITE AND FRIZZLING IN THE FOWL[1]

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THIS paper presents data which establish through linkage relationships the arrangement in one chromosome of the three genes, *Cr, I* and *F,* representing the incompletely dominant characters, crest, dominant white and frizzling, respectively. Data are also adduced to show that the gene for cerebral hernia, previously reported to be linked with *I,* is probably identical with the gene for crest.

PREVIOUS STUDIES

Data presented by Dunn and Landauer (1930) made it clear that there is close linkage of the gene for dominant white with that for cerebral hernia, which they considered to be independent of the gene for crest. Subsequently, Hutt (1933) showed that dominant white, *I,* is closely linked with frizzling, *F,* there being about 18 per cent. crossing-over between the two. Meanwhile, Suttle and Sipe (1932) had reported *F* to show about 28 per cent. crossing-over with the gene for crest, *Cr.* It was evident, therefore, that *Cr, I, F* and the gene for cerebral hernia were all in one chromosome, but their arrangement was not definitely established because the linkage relationship of *I* and *Cr* had not been determined. If the arrangement were *I–F–Cr,* then *Cr* and *I* should show something less than 46 per cent. crossing-over, but, if their linear order were *Cr–I–F,* then the cross-over percentage should be approximately 11 or 12 per cent.

[1] Contribution No. 89 from the Department of Poultry Husbandry, Kansas State College, and No. 1362 of the Journal Series of the Minnesota Agricultural Experiment Station.

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LINKAGE DATA

The writers have independently made genetic tests to permit accurate mapping of this chromosome and, in order to present all the available data in one place and to avoid unnecessary expansion of the literature on genetics of the fowl, have collaborated in the presentation of results.

The three characters, crest, dominant white and frizzling, are all incompletely dominant unifactorial characters which have been adequately described in previous papers. Chicks can be classified for the presence or absence of crest with a high degree of accuracy as soon as hatched, but, in order to be more accurate, data concerning crest in this paper are restricted to adult classifications. Dominant white is easily recognized in heterozygotes at hatching. It was shown by Hutt (1930) that chicks can be classified accurately for the presence or absence of frizzling as early as 9 days after hatching, but, since extremely slow-feathering birds may present difficulties in classification, the data concerning frizzling are restricted in this paper to those chicks for which two consistent consecutive classifications were made after 9 days of age.

Cross-over data for the three possible combinations in pairs of *Cr, I* and *F* are presented in Tables 1, 2, and 3. In every case crossing-over was measured by back-crossing heterozygotes to double or triple recessives. Since the three genes all have been shown previously to be autosomal, the data for the back-cross progeny are not presented separately for each sex. When the progeny from any one bird under test were numerous enough to afford a reasonably accurate measure of crossing-over in that bird, they are presented separately. This is done to record the variation among the birds with respect to the amount of crossing-over in their germ cells.

Cr and I

In a previous paper, Warren (1933) presented data on tests for linkage in 35 of the 36 possible combinations in

TABLE 1

LINKAGE RELATIONS OF CREST AND DOMINANT WHITE (BACK-CROSS DATA)

Bird No.	Crossing-over in male—coupling						
	Non-cross-overs		Cross-overs		Total gametes tested	Total cross-overs	Per cent. crossing-over
	Cr I	cr i	Cr i	cr I			
Males							
Kans. 1212M	96	110	11	19	236	30	12.7
Kans. 1216M	119	103	10	12	244	22	9.0
Kans. 1259M	122	124	13	15	274	28	10.2
Total	337	337	34	46	754	80	10.6
	Crossing-over in male—repulsion						
	Cr i	cr I	Cr I	cr i			
Males							
Kans. 1289M	82	86	13	16	197	29	14.7
Kans. 1301M	33	37	3	4	77	7	9.1
Minn. B2237	61	67	8	10	146	18	12.3
Minn. B2240	67	47	9	7	130	16	12.3
Minn. C2223	15	22	5	6	48	11	22.9
Minn. 3 birds	19	26	4	6	55	10	18.2
Total	277	285	42	49	653	91	13.9
Total all males	614	622	76	95	1407	171	12.2
	Crossing-over in female—coupling						
	Cr I	cr i	Cr i	cr I			
Females							
Kans. 9007A	13	18	2	3	36	5	13.9
Kans. 9012A	19	18	3	2	42	5	11.9
Kans. 9014A	12	20	3	3	38	6	15.8
Kans. 9015A	13	12	2	2	29	4	13.8
Kans. 9016A	10	23		3	36	3	8.3
Kans. 9018A	16	15	2	3	36	5	13.9
Kans. 9019A	21	17		4	42	4	9.5
Kans. 9020A	16	18	6	4	44	10	22.7
Kans. 9115A	30	19	5	2	56	7	12.5
Kans. 9183A	33	25	1	2	61	3	4.9
Kans. 9184A	10	13	1	2	26	3	11.5
Kans. 9185A	10	7	4	4	25	8	32.0
Kans. 6 birds	32	27	7	5	71	12	16.9
Total	235	232	36	39	542	75	13.8
	Crossing-over in female—repulsion						
	Cr i	cr I	Cr I	cr i			
Females							
Minn. 3 birds	16	17	2	0	35	2	5.7
Total all females	251	249	38	39	577	77	13.3
Total both sexes					1984	248	12.5

pairs of 9 autosomal characters which were submitted to test. None of these showed any linkage. The only one of the 36 pairs not tested was *Cr* and *I*, and the only reason they were not tested was that the stock prepared for that purpose came to untimely deaths. That this pair of genes does show quite close linkage is now established by the data in Table 1.

The gene for crest used in the Minnesota tests and in the Kansas male 1289M was derived from Houdans, but in all other Kansas data the *Cr* gene originated from Silkies.

The following observed ratios, summarizing data in Table 1, show that a normal segregation was obtained for each pair of genes:

Dominant white: colored – 1003: 981
Crested: non-crested – 979: 1005

The percentage of crossing-over, based on a total of 1,984 gametes, is 12.5, but the variation from bird to bird is quite marked. Disregarding the smaller families, there is a range from 4.9 per cent. (in ♀ 9183A) to 32.0 per cent. (in ♀ 9185A). Much of this variation is probably due to the smallness of the sample, but some of it may be attributed to individual variability in amount of crossing-over.

I and F

Proof that these two genes were linked with about 18 per cent. crossing-over between them was given by Hutt (1933). The additional data presented in Table 2 are in quite close agreement with the previous findings.

The Frizzles used by both of us were descended from the same English stock as that used by the junior author in earlier work. Considering the new data in Table 2, the following ratios were observed in the backcross:

Frizzled: non-frizzled – 448: 385
Dominant white: colored – 429: 404

These two ratios indicate a segregation of the genes *F* and *I* reasonably close to the expected 1:1 ratio. Cross-

TABLE 2

LINKAGE RELATIONS OF DOMINANT WHITE AND FRIZZLING
(BACK-CROSS DATA)

Bird No.	Crossing-over in male—coupling						
	Non-cross-overs		Cross-overs		Total gametes tested	Total cross-overs	Per cent. crossing-over
	F I	f i	F i	f I			
Males							
Kans. 1289M	156	143	34	28	361	62	17.2
Kans. 1301M	32	25	12	8	77	20	26.0
Minn. B2209	35	34	10	6	85	16	18.8
Minn. B2249	22	27	2	2	53	4	7.5
Minn. B2840	26	23	3	2	54	5	9.3
Minn. C2223	24	17	4	3	48	7	14.6
Minn. 6 birds	45	36	9	7	97	16	16.5
Total	**340**	**305**	**74**	**56**	**775**	**130**	**16.8**
	Crossing-over in female—coupling						
Females							
Minn. 13 females	29	20	5	4	58	9	15.5
	Previously published results						
	Hutt—repulsion in female				157	31	19.7
	—coupling in female				33	6	18.2
	—coupling in male				82	13	15.9
	Grand total in females				**248**	**46**	**18.5**
	Grand total in males				**857**	**143**	**16.7**
	Grand total in both sexes				**1105**	**189**	**17.1**

ing-over in 1,105 gametes, which comprise all the available data on this pair of genes, was 17.1 per cent. It is noteworthy that the amount of crossing-over varied in different males from 7.5 to 26 per cent.

Cr and F

The *Cr* gene used by both of us in measuring the linkage relationship of these two genes was derived from Houdans. The new data presented in Table 3 yield the following ratios:

Frizzled: non-frizzled – 200: 161
Crested: non-crested – 162: 199

While there is an excess of frizzled birds and of non-crested ones, the deviations from the expected ratio are not greater than might occur by chance. The amount of crossing-over in our data, 30.2 per cent. in 361 gametes, is remarkably close to the 28.5 per cent. found by Suttle and Sipe (1932) in the 316 gametes tested by them.

TABLE 3

LINKAGE RELATIONS OF CREST AND FRIZZLING (BACK-CROSS DATA)

Bird No.	Non-cross-overs		Cross-overs		Total gametes tested	Total cross-overs	Per cent. crossing-over
	F cr	f Cr	F Cr	f cr			
	Crossing-over in male—repulsion						
Males							
Kans. 1289M	66	55	26	22	169	48	28.4
Kans. 1301M	30	21	15	11	77	26	33.8
Minn. C2223	19	11	9	9	48	18	37.5
Minn. 2 birds	16	10	2	4	32	6	18.8
Total	131	97	52	46	326	98	30.1
	Crossing-over in female—repulsion						
Females							
Minn. 3 birds	14	10	3	8	35	11	31.4
	Previously published results						
Suttle and Sipe—							
Crossing-over in female					235	68	28.9
Crossing-over in male					81	22	27.2
Grand total in males					407	120	29.5
Grand total in females					270	79	29.3
Grand total in both sexes					677	199	29.4

MAP OF THE CHROMOSOME

The theoretical map distance *Cr* to *F* measured by the cross-over percentages for its two component parts is $12.5 + 17.1 = 29.6$, and the actually observed distance as directly measured by crossing-over between *Cr* and *F* is 29.4. If double crossing-over should occur in the distance between *Cr* and *F*, it would reduce the cross-over percentage for this pair of factors. Double crossing-over should make the map distance between *Cr* and *F*, as

measured by the percentage of crossing-over between these two factors, less than that calculated from adding the distances *Cr* to *I* and *I* to *F*. The map distance between *Cr* and *F*, as calculated by the former method, is 29.4 and by the latter, 29.6. The difference between these two values is not statistically significant and furnishes no evidence for double crossing-over occurring in the map distance between these two factors.

Independent confirmation of this suggested map is found in data presented by Sungurov (1933) who observed 21 per cent. crossing-over between *I* and *F*, and 33.6 per cent. crossing-over between *Cr* and *F*. Data on the *Cr* and *I* relationship were apparently not secured. Unfortunately, this paper is known to us only through an abstract which does not give the actual numbers involved.

Double Crossing-over

In order to permit simultaneous measurement of crossing-over between *Cr* and *I*, *Cr* and *F*, and *I* and *F*, a triheterozygous stock of the genotype $\frac{F\ I\ cr}{f\ i\ Cr}$ was produced at Minnesota by crossing *F I* birds with Houdans which carried *Cr*. One of these birds was sent to the senior author and others were tested at Minnesota. The combined results are shown in Table 4.

Since the frequency of crossing-over between *Cr* and *I* is 12.5 per cent., and of that between *I* and *F*, 17.1 per cent., the probability of getting simultaneous crossing-over in the two regions is theoretically $12.5 \times 17.1 = 2.13$ per cent., provided that crossing-over in one region is unaffected by crossing-over in the other. In the observed population of 284 gametes the theoretical expectation would be 6.05 double cross-overs, where in fact none was found. The deficiency might be ascribed to chance, but it is more likely due to the phenomenon of interference whereby a cross-over in one region reduces the chance of a cross-over in an adjacent region. The data from these triheterozygous birds, therefore, show that the fowl con-

TABLE 4

THREE-POINT TEST FOR LINKAGE OF *F*, *I* AND *Cr*

	Non-cross-overs		Cross-overs between F & I		Cross-overs between I & cr		Double cross-overs between F & cr		Total gametes tested
	F I cr	f i Cr	F/i Cr	f/I cr	f i/cr	F I/Cr	F/i/cr	f/I/Cr	
Minn. ♂ C2213	8	7	1	1	2	0	0	0	19
Minn. ♂ C2216	6	3	1	0	1	0	0	0	11
Minn. ♂ C2223	19	11	4	3	6	5	0	0	48
Minn. 3 ♀♀	14	10	3	6	0	2	0	0	35
Kans. ♂ 1289M	67	58	13	10	12	11	0	0	171
Total	114	89	22	20	21	18	0	0	284

forms to the behavior observed in other species adequately investigated genetically in that it exhibits the phenomenon of interference. They also confirm the actual measurements of crossing-over, which, since the crossing-over between *Cr* and *F* agrees closely with the sum for the two component parts of that distance, indicate that in this region of the chromosome there is very little, if any, double crossing-over in a distance of approximately 29 cross-over units.

Cerebral Hernia

The literature on the genetic status of cerebral hernia is somewhat confusing. Krautwald (1910) concluded from his anatomical studies that crest is the outward expression of the underlying condition causing cerebral hernia, namely, an accumulation of fluid in the ventricles of the brain, which he described as *hydrocephalus internus.* He observed not only that cerebral hernia never appeared without crest, but also that the size of the crest was always directly proportional to the degree of cerebral hernia. The relationship between the extent of hernia and the size of crest was mentioned by earlier investigators and has been verified by the present writers. Moreover, as Krautwald demonstrated, in the somewhat similar condition in the duck, an encephalocoel occurring in the parieto-occipital region is invariably associated with crest in that region. In both these species, therefore, the crests, though occurring in the chicken in the frontal region of the cranium, and in the duck in the parieto-occipital region, are associated with underlying abnormalities in the brain. It seems unlikely that this would occur unless both crest and cerebral hernia resulted from one and the same underlying cause. In both species the character is hereditary.

The idea that crest might be due to one gene and cerebral hernia to another apparently originated with Davenport (1906), who concluded from his not-very-extensive data that the latter was recessive, the former dominant.

This conclusion was accepted by Dunn and Jull (1927) and by Dunn and Landauer (1930), who obtained some evidence that dominant white and cerebral hernia were linked, with about 11 per cent. crossing-over between them. It should be noted that their determination, though based on very small numbers, agrees closely with the cross-over percentage of 12.5 between *Cr* and *I* determined by the present writers.

Considering all the available data, the observations of Krautwald and especially the fact that no one has yet produced fowls with cerebral hernia and without crest or observed the segregation of such fowls from crested and herniated breeds, it seems fairly certain that one gene only is responsible for these two conditions. A similar view-point was recently expressed by Fisher (1934), who found about 25 per cent. of herniated fowls in an unstated number of offspring from a mating *inter se* of heterozygous crested birds.

If the above hypothesis be accepted, there is some difficulty in explaining the irregular incidence of cerebral hernia in matings involving crest. In Table 5 are pre-

TABLE 5
THE INCIDENCE OF CEREBRAL HERNIA IN MATINGS INVOLVING CREST

Type of mating	Crested-cerebral hernia	Crested non-cerebral hernia	Non-crested-non-cerebral hernia
Heterozygous crest by non-crest:			
1262M	4	4	3
1280M	9	30	38
1300M	6	31	42
Total	19	65	83
Heterozygous crest by homozygous crest-hernia:			
1289M	16	132	0
1287M	23	47	0
Total	39	179	0
Heterozygous crest by heterozygous crest:			
1287M	9	46	26

sented data secured at Kansas State College bearing on the relationship of these two conditions.

It will be noted that among fowls from the mating of *Cr cr* × *cr cr* birds, some with hernia appeared. The explanation might be offered that the supposedly non-crested birds had crests which were overlooked, since the crests of heterozygous birds sometimes are quite small, but the resulting approximately equal numbers of crested and non-crested progeny belie this explanation and indicate that the cross was really a back-cross of heterozygous to non-crested birds. All the non-crested breeders came from uncrested ancestors. This means that cerebral hernia appeared in birds heterozygous for crest. Numerous matings of this type have been observed in which no cerebral hernia appeared, but the matings are given in Table 5 to demonstrate that hernia does sometimes appear in birds not homozygous for crest.

From matings of *Cr cr* × *Cr Cr* herniated birds there was obtained a population all crested as expected but with a ratio of 39 herniated to 179 non-herniated, where equality of these two classes would be expected if the *Cr Cr* genotype were always manifested as hernia. It would appear either that many *Cr Cr* birds do not exhibit hernia, or else that a large percentage of the herniated birds fail to hatch.

Finally, from heterozygous crested birds mated together there were secured only 9 herniated birds in a population of 81, where about 20 *Cr Cr* birds, all herniated, would be expected if the character were fully expressed.

These apparently inconsistent data can be accounted for in either of two ways or in both together. It is suggested that cerebral hernia and crest result from the gene *Cr* and that manifestation of hernia (which is really not accurately measured by the method of palpation employed in all genetic studies to date) is subject to varying degrees of "penetrance" in the sense of Timoféeff-Ressovsky. Ordinarily the hernia is not expressed in hetero-

zygotes, but in exceptional cases it may be. Ordinarily it is manifested in homozygotes, but in some genotypes it is not present to a degree detectable by the comparatively inaccurate methods of palpation and visual inspection in the down-covered chick. Behavior of this irregular type was encountered in the *radius incompletus* and abnormal abdomen characters in *Drosophila funebris* by Timoféeff-Ressovsky (1927, 1932) and has also been found by the junior author in the character "down-defect" in fowls (Hutt, 1932) which may appear in some heterozygotes and not at all in some homozygotes. Such irregular penetrance may be attributed to the effects of modifying genes, which, though numerous, differ in number and effects in any but relatively homozygous lines.

Such behavior would explain the irregular ratios shown in Table 5. There may also be involved some mortality in the homozygotes from an abnormality resulting from a double dose of the *Cr* gene. The incubation records for the matings in Table 5 do not show excessive mortality in the mating of *Cr cr* × *Cr Cr* and of *Cr cr* × *Cr cr*, where it would be expected if anywhere, in comparison with the *Cr cr* × *cr cr* matings where it would not be expected.

In connection with this hypothesis, it should be remembered that Rüst (1932) obtained very fair evidence that crested ducks are heterozygous for a gene which is lethal to the majority, if not all, of the homozygotes. Moreover, this gene is apparently expressed in only about half of the heterozygotes, the other half being indistinguishable from ordinary uncrested ducks. Apparently a somewhat similar variability occurs in the crested fowls, except that homozygosity for *Cr*, if lethal at all, affects only a few of the embryos. The records of hatchability for the matings given in Table 5 were not exceptionally poor and would not account for the great shortage of herniated birds. Heterozygotes in the fowl manifest the crest, but may or may not manifest cerebral hernia. Similarly, some homozygotes do not manifest hernia.

This variability in the expression of cerebral hernia is quite in accord with the early history of that character. Darwin (1868) cites the statements of both Blumenbach and Bechstein that originally hernia was restricted to females, but that, by artificial selection in affected breeds, the males came to manifest the character. This merely indicates that it is much subject to modifying factors, as might be expected from its very irregular penetrance discussed above. A similar sex difference in penetrance was noted by Timoféeff-Ressovsky (1927) in *Drosophila funebris* and has been observed by the junior author (unpublished data) in the down-defect character mentioned above.

Genes Independent of the *Cr I F* Chromosome

In former papers (Warren, 1933; Hutt, 1933) there were presented data showing independent assortment of many genes which had been adequately tested for linkage with *Cr, I* or *F*. Since then the additional data presented in Table 6 have become available. Undated tests ascribed to the present authors represent data previously unpublished.

It is evident that no other genes have yet been shown to be linked with *Cr, I* or *F*. Landauer (1933) has published some data in support of his view that rumplessness is linked with frizzling. He himself has produced good evidence that rumplessness is independent of crest, and Warren has found it independent of both dominant white and crest. Since *Cr* and *I* belong to the same linkage group as *F*, it seems unlikely that the comparatively loose linkage reported will be substantiated when adequate data have been obtained.

Sungurov (1933) has suggested that the rose comb-creeper linkage group may belong to the same chromosome as *Cr, I* and *F*, but adequate support for this hypothesis has not yet been adduced. In fact, unpublished data secured at Kansas State College strongly support the view that rose comb segregates independently of *Cr*

TABLE 6

CHARACTERS APPARENTLY INDEPENDENT OF THE *Cr I F* GROUP

Linked gene	Tested with	Investigator	Back-cross ratio*
Cr	Muff	Hutt	202 – 185
Cr	Muff	Warren	105 – 98
Cr	Duplex comb	Warren	199 – 210
Cr	Duplex comb	Hutt	210 – 179
Cr	Flightless	Warren	202 – 200
Cr	Rumplessness	Landauer (1933)	246 – 256
I	Rumplessness	Warren	310 – 287
I	Muff	Hutt	199 – 191
I	Muff	Warren	207 – 209
I	Muff	Serebrovsky and Petrov (1930)	93 – 101
I	Duplex comb	Warren	230 – 242
I	Duplex comb	Hutt	240 – 213
I	Silkie	Warren	94 – 71
I	Flightless	Warren	135 – 135
F	Rumplessness	Landauer (1933)	259 – 190
F	White skin	Warren	85 – 82
F	Polydactyly	Warren	108 – 114
F	Polydactyly	Hutt	55 – 52
F	Muff	Warren	181 – 171
F	Muff	Hutt	45 – 46
F	Duplex comb	Warren	121 – 109
F	Duplex comb	Hutt	51 – 41

* The ratio given is that of parental combinations to new combinations.

and *I*. The data from back-cross matings are 377 parental combinations to 334 new combinations in the test with *I* and 374 to 355 in the test with *Cr*.

SEX DIFFERENCES IN AMOUNT OF CROSSING-OVER

There are recorded here sufficiently large numbers, and factors which show high enough percentage of crossing-over, to secure fair evidence for the relative amount of crossing-over in the two sexes. When the data in Tables 1, 2 and 3 are summarized for each sex, the following rates of crossing-over are found:

The figures in parentheses give the number of gametes tested in each case. These results indicate that the rates of crossing-over are very similar in the two sexes of the

Genes	Perecentage of crossing-over in ♂♂	in ♀♀
Cr and *I*	12.2 (1407)	13.3 (577)
I and *F*	16.7 (857)	18.5 (248)
Cr and *F*	29.5 (407)	29.3 (270)

fowl, but that there appears to be a slight tendency for a higher rate in the females. This is in agreement with the data of Landauer (1933), and of Taylor (1934) who, from large numbers for the closely linked genes for rose comb and creeper, concur in finding slightly more crossing-over in females than in males.

Summary

The data here presented definitely establish the fact that crest, dominant white and frizzling belong to the same linkage group.

It is shown that these genes have the arrangement in the chromosome of *Cr–I–F* with approximately 12 per cent. crossing-over between *Cr* and *I* and 17 per cent. between *I* and *F*. Since the percentage of crossing-over between *Cr* and *F* is 29, the distance in the chromosome between *Cr* and *F*, as measured by the summation of the segments *Cr* to *I* and *I* to *F*, is practically identical with that secured by directly measuring the percentage of crossing-over between *Cr* and *F*.

This indicates that little double crossing-over occurs in the approximate distance of 29 units on this chromosome. In segregation of these genes in birds heterozygous for all three, no double cross-overs were recorded in 284 gametes.

Evidence is adduced to support the view that cerebral hernia is ordinarily the homozygous expression of crest, but a number of irregularities were found in the manifestation of cerebral hernia. It may appear in heterozygotes or may be suppressed in homozygotes.

The rates of crossing-over were very similar in the two sexes, there being some evidence for a slightly higher amount in females.

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SHORTER ARTICLES AND DISCUSSION

LINKAGE STUDIES IN THE RAT

BLUE dilution, which occurred as a mutation in our experimental rats, was reported in 1929.[1] Black color is diluted to one of slate color much like the blue dilution found in other mammals (see Fig. 1). The difference between dilution and intense color is due to a single gene, as shown in Table 1.

Tests have been made which provide data for the study of linkage relations between dilution (d) and the following genes: A—agouti, a—non-agouti; H—self-color, h—hooded; R—normal dark eye, r—red-eyed; Hy—normal hair, hy—hairless (hypotrichosis).

TABLE 1

SEGREGATION OF INTENSITY AND DILUTION IN MATINGS OF HETEROZYGOTES AND BACKCROSSES

Parents	Progeny	
	Intense	Dilute
♀ Dd × ♂ Dd	605	204
♀ Dd × ♂ dd	453	404
♀ dd × ♂ Dd	216	171
Totals	669	575

In tests for linkage two kinds of crosses were made: (1) heterozygous individuals to double recessives, which theoretically would give, if no linkage existed, four classes in equal numbers, and (2) heterozygous individuals mated *inter se* except for the tests with non-agouti and hooded, which would give four phenotypes in a theoretical ratio of 9 : 3 : 3 : 1.

Hairlessness and dilution: Backcrosses gave the following results:

Intense haired DHy	Intense hairless Dhy	Dilute haired dHy	Dilute hairless dhy
142	148	125	128

The parental combinations of 270 and the new combinations of 273 indicate that d and hy are independent. A cross with both parents heterozygous (DdHyhy) gave the following classes:

[1] E. Roberts, *Science*, 70: 334, 1929.

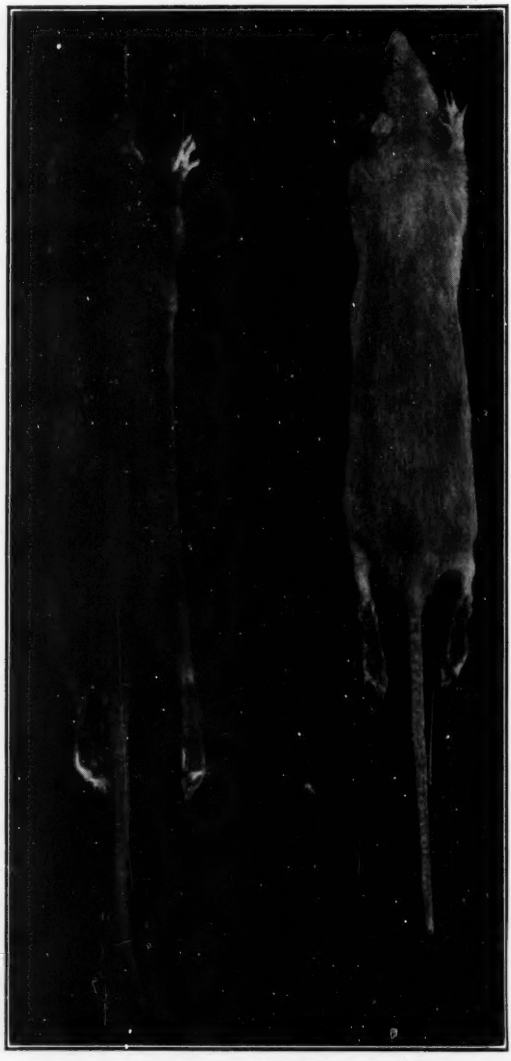

FIG. 1. On the left is an intense black rat and on the right a dilute.

Intense haired	Intense hairless	Dilute haired	Dilute hairless
DHy	Dhy	dHy	dhy
77	31	18	13

The theoretical expectation on the basis of independence would be, in whole numbers, 78, 26, 26 and 9, respectively. The departure of the observed from this theoretical ratio gives no indication of linkage.

Non-agouti and dilution: The results of backcrosses for testing linkage of non-agouti and dilution were:

Intense agouti	Intense non-agouti	Dilute agouti	Dilute non-agouti
DA	Da	dA	da
144	152	133	126

The parental combinations of DA + da = 270 and the new combinations Da + dA = 285 are not significantly different from the theoretical expectation if non-agouti and dilution are independent.

Hooded and dilution: The backcross gave in this case:

Intense self-color	Intense hooded	Dilute self-color	Dilute hooded
DH	Dh	dH	dh
175	128	142	125

The parental combinations of DH + dh = 300 and new combinations of Dh + dH = 270 are within the expectation if hooded and dilution are independent.

Red eye and dilution: In the backcross the following classes were obtained:

Intense dark eye	Intense red eye	Dilute dark eye	Dilute red eye
DR	Dr	dR	dr
158	163	146	147

The parental combinations DR + dr = 305 and the new combinations of Dr + dR = 299 indicate the absence of linkage. The matings when both parents were heterozygous gave:

Intense dark eye	Intense red eye	Dilute dark eye	Dilute red eye
DR	Dr	dR	dr
158	56	40	16

If not linked, the theoretical ratio would be 152:51:51:17 expressed in closest whole numbers.

Table 2 gives the data for the various crosses described above. King and Castle[2] found no linkage between dilution and curly.

TABLE 2

TESTS FOR LINKAGE OF DILUTION (d) WITH HAIRLESSNESS (hy), NON-AGOUTI (a), HOODED (h), AND RED-EYE (r)

Parental constitution		Progeny-phenotype				Parental combinations	New combinations	D/E	P
		DHy	Dhy	dHy	dhy	DHy + dhy	Dhy + dHy		
♀ DHy/dhy × ♂ dhy/dhy		122	120	102	115	237	222		
♀ dhy/dhy × ♂ DHy/dhy		20	28	23	13	33	51		
Totals	O	142	148	125	128	270	273	0.129	
	E	135.7	135.7	135.7	135.7	271.5	271.5		
♀ Dhy/dHy × ♂ Dhy/dHy	O	77	31	18	13				0.160
	E	78	26	26	9				
		DA	Da	dA	da	Da + da	Da + dA		
♀ DA/da × ♂ da/da		115	131	112	108	223	243		
♀ da/da × ♂ DA/da		29	21	21	18	47	42		
Totals	O	144	152	133	126	270	285	0.637	
	E	138.7	138.7	138.7	138.7	277.5	277.5		
		DH	Dh	dH	dh	DH + dh	Dh + dH		
♀ DH/dh × ♂ dh/dh		138	106	117	103	241	223		
♀ dh/dh × ♂ DH/dh		37	22	25	22	59	47		
Totals	O	175	128	142	125	300	270	1.258	
	E	142.5	142.5	142.5	142.5	285	285		
		DR	Dr	dR	dr	DR + dr	Dr + dR		
♀ DR/dr × ♂ dr/dr		121	133	116	117	238	239		
♀ dr/dr × ♂ DR/dr		37	30	30	30	67	60		
Totals	O	158	163	146	147	305	299	0.244	
	E	151	151	151	151	302	302		
♀ Dr/dR × ♂ Dr/dR	O	158	56	40	16				0.371
	E	152	51	51	17				

In the study of linkage relations of hypotrichosis or hairlessness with other genes as well as in the study of dilution, various matings involving agouti, self-color, albinism and red-eye were made. While the results of these matings show nothing new in respect to linkage relations, yet they are given in Table 3 in order that they may, if so desired, be combined with data already published by other workers which show these characters to be independent.

[2] Helen Dean King and W. E. Castle, *Proc. Nat. Acad. Sciences*, **21**: 390–399, 1935.

TABLE 3

LINKAGE TESTS OF NON-AGOUTI (a) AND HOODED (h); HOODED (h) AND RED-EYE (r); NON-AGOUTI (a) AND RED-EYE (r); ALBINISM (c) AND NON-AGOUTI (a); AND ALBINISM (c) AND HOODED (h)

Parental constitution		Progeny-phenotype				Parental combinations	New combinations	D/E	X^2
		AH	Ah	aH	ah	AH + ah	Ah + Ah		
♀ AH/ah × ♂ ah/ah		159	128	149	136	295	277		
♀ ah/ah × ♂ AH/ah		28	20	20	16	44	40		
Totals	0	187	148	169	152	339	317	.861	5.82
	E	164	164	164	164	328	328		
♀ AH/ah × ♂ AH/ah	0	293	95	82	39				3.67
	E	286.3	95.4	95.4	31.8				
		HR	Hr	hR	hr	HR + hr	Hr + hR		
♀ HR/hr × ♂ hr/hr		139	137	113	115	254	250		
♀ hr/hr × ♂ HR/hr		26	22	21	15	41	43		
Totals	0	165	159	134	130	295	293	.082	6.30
	E	147	147	147	147	294	294		
		AR	Ar	aR	ar	Ar + ar	Ar + aR		
♀ AR/ar × ♂ ar/ar		125	123	127	129	254	250		
♀ ar/ar × ♂ AR/ar		25	23	22	14	39	45		
Totals	0	150	146	149	143	293	295	.082	0.20
	E	147	147	147	147	294	294		
		CA	Ca	cA + ca					
♀ CA/ca × ♂ CA/ca	0	356	120	160					0.03
	E	358	119	159					
		CH	Ch	cH + ch					
♀ CH/ch × ♂ CH/ch	0	354	122	160					0.13
	E	358	119	159					

SUMMARY

The linkage studies reported in this paper show that dilution recombines independently of the genes for agouti and non-agouti (A, a), self-color and hooded (H, h), haired and hairless (Hy, hy) and dark color of eye and red-eye (R, r). Since red-eye, albinism and pink-eye are linked and since dilution is independent of red-eye, it can not be in this linkage system.

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BODY WEIGHT OF SNAILS WITH REFERENCE TO HEALTH AND PARASITISM

'DURING the course of some experiments carried on in the summer of 1933[1] in an attempt to check the temperature reactions of snails in health and parasitism, it was noticed that the diseased snails averaged greater in weight than did the healthy ones. In order to check this observation, some former data[2] were gone over, and it was found that the same condition was the case.

In the summer of 1933, 62 individuals of *Lymnaea stagnalis* were subjected to measurements of temperature. Of these, 35 were healthy and 27 were parasitized. The minimum weight in the healthy group was 3.000 grams; the maximum 6.400 grams; the average 4.029 grams. In the parasitized group the minimum weight was 3.400 grams; the maximum 6.400 grams; the average 4.881 grams. In these experiments the diseased snails averaged 0.852 gram per individual heavier than the healthy ones.

In the former (1927) data, 56 individuals of *Physa occidentalis* were checked for carbon dioxide elimination. These were divided equally between healthy and parasitized ones, 28 in each case. The healthy individuals had a minimal weight of 0.0260 gram, a maximal weight of 0.1461 gram and an average weight of 0.0777 gram. The parasitized ones were 0.0241 gram, 0.1751 gram and 0.0867 gram in weight in the same order. This would give the parasitized group a greater average weight per individual of 0.0090 gram.

The same body of data records the results of 50 tests for oxygen consumption in *Physa occidentalis*. These were evenly divided between healthy and parasitized individuals, 25 in each case. In the case of the healthy ones the minimum weight was 0.0627 gram, the maximum 0.1621 gram and the average 0.0948 gram. The figures for the parasitized ones were 0.0620 gram, 0.1702 gram and 0.0962 gram, respectively, in the same order. The parasitized members of this group were on the average 0.0014 gram heavier per individual than were the healthy ones.

Physa occidentalis is a much smaller snail than is *Lymnaea stagnalis*. The weights of the former snail were checked to the

[1] C. T. Hurst and C. R. Walker. "Increased Heat Production in a Poikilothermous Animal in Parasitism," AMERICAN NATURALIST, 69: 724, 461–466, September–October, 1935.

[2] C. T. Hurst. *Univ. Calif. Publ. Zool.*, Vol. 29, No. 14, 1927.

nearest milligram; those of the latter to the nearest ten milligrams.

Since these data were suggestive of the possibility of an actual greater average weight for parasitized snails over healthy ones of the same species, it was thought advisable to seek further data to bear upon this question. Accordingly, during the course of a study of the excretory system of a certain Furcocercous cercaria harbored by *Lymnaea stagnalis*, a record was kept of the infected and the healthy snails together with their weights. Of 132 snails for which weight records were kept in this latter study, 88 were healthy and 44 were parasitized. The healthy individuals showed a minimal weight of 0.870 gram, a maximal weight of 5.250 grams, and an average weight of 3.028 grams. The values for the parasitized group were 1.000 gram, 7.650 grams and 3.931 grams, respectively, in the same order. The latter group averaged 0.903 gram per individual heavier than the former group.

A further body of data was collected in that 100 more individuals of *Lymnaea stagnalis* were examined for weight alone as related to health and disease. Of these, 88 proved to be healthy and only 12 parasitized. Of the 88 healthy specimens, the minimal weight was 2.150 grams, the maximal weight was 4.670 grams and the average was 3.232 grams. In the same order the values for the parasitized group of 12 were 2.190 grams, 5.060 grams and 3.783 grams, respectively. The latter group averaged 0.551 gram per individual heavier than the former group.

It would appear then that in the case of parasitism of snails by fluke larvae the parasitized individuals, on the average, are heavier ones than the healthy ones. The data for the 400 snails recorded here are summarized in Table I.

No certain cause can be assigned to the condition here reported. Several lines of thought may, however, be examined for what they are worth. In the first place, it may be said that the greater weight of diseased snails may possibly be due to the added weight of the contained parasites. At first glance this would appear logical. But, in many cases, especially in heavy cases of parasitism, snail tissue is replaced by parasites. In some instances no trace of a gonad may be found—its place is occupied by a solid mass of parasites. Also, the interstitial tissue of the hepato-pancreas may be largely broken down and

TABLE I

Snail	Condition	*Max. Wt.	*Min. Wt.	*Avg. Wt.	No. Cases
Lymnaea	Healthy	6.400	3.000	4.029	35
	Parasitized	6.400	3.400	4.881	27
Physa	Healthy	0.1461	0.0260	0.0777	28
	Parasitized	0.1751	0.0241	0.0867	28
Physa	Healthy	0.1621	0.0627	0.0948	25
	Parasitized	0.1702	0.0620	0.0962	25
Lymnaea	Healthy	5.250	0.870	3.028	88
	Parasitized	7.650	1.000	3.931	44
Lymnaea	Healthy	4.670	2.150	3.232	88
	Parasitized	5.060	2.190	3.783	12
	Total number of cases				400

* In grams.

its place occupied by parasites. In general, it would appear that fluke infection of snails does not increase the weight of the infected individual by the mere physical addition of gross weight.

Another possibility is that perhaps for some problematical reason the younger or lighter snails may, on the average, escape infection more often than the older or heavier individuals. Such might possibly be due to the seasonal factors involved in the fluke cycle and in the snail's breeding season as they may be interrelated with each other. Young snails hatched after the season for free-swimming miracidia would perhaps escape infection until the following spring. Or further, recovery and reinfection may be possible. Older and heavier snails that may have recovered would again be exposed to infection on even terms with younger and lighter ones that never were infected. As a matter of fact, the whole problem of immunity of snails to such infections is as yet in an unsatisfactory state of clarity.

Perhaps the best interpretation to place on the data herein reported is that there is a very high rate of mortality that kills off the snails in the earlier stages of disease and leaves survivors that are naturally older and heavier than those that succumbed. The more hardy individuals would be able to carry their infections and live out their lives—the less hardy ones would die. Then, as a matter of course, the diseased group would, on the average, be composed of older and presumably heavier indi-

viduals than the healthy group in which the younger members had not been subjected to the decimating influence of parasitism.

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THE OCCURRENCE OF ALBINO AND SPOTTED RATS UNDER FERAL CONDITIONS

WHILE on a short visit to the island of Lanai, which is some 55 nautical miles southeast of Honolulu, Hawaii, I was surprised to find albino and spotted house rats (*Rattus norvegicus*) living in the fields under natural conditions. As I was on the island for two days only superficial obesrvations could be made. However, in the two dozen traps which were set out for two nights thirteen house rats were taken. Of these one was an albino with pure white hair and pink eyes and another was a spotted individual with white belly and sides. The rest of the animals were normally pigmented *Rattus norvegicus*.

According to reports from several foremen with whom I talked, albino and spotted rats (the latter they call "Holsteins") are quite common in the pineapple fields as well as in the houses and buildings of Lanai City. The presence of these albinos and "Holsteins" is not necessarily due to an independent mutation of these characters among the local rats, but is generally attributed to the fact that Filipino plantation hands have brought in white rats as pets to Lanai, and some of these have escaped. The fact that they have adapted themselves to the natural conditions and have interbred to such an extent as to be noticeable to the people living there is in itself of interest to biologists.

Davenport, in his experiments on the discriminate selection of conspicuously colored chickens by hawks, found that the white and black fowl were the first to be eliminated, whereas the inconspicuously colored ones survived. There was then a natural selection taking place, with a premium being paid on inconspicuousness. On the island of Lanai there is evidently no such selection taking place, since the conspicuous animals are not only maintaining themselves but evidently increasing in numbers. This is due perhaps to the fact that food is abundant, there is no competition for habitat and predatory animals are few in number. The mongoose (*Herpestes griseus*) has not been introduced to this island, and the feral domestic cats as well as the native owls (*Asio accipitrinus sandvicensis*) are so few in number that they play

a very ineffectual part as predators. Here, then, is an example of negative natural selection where the survival of the fittest, owing to the elimination of the less fit, is practically non-existent.

Oceanic islands are of great interest to the zoogeographers because of a number of characteristics, one of them being the presence of peculiar animals which usually occur nowhere else. The faunal peculiarities of these islands may be partially explained on the basis that the environment is such as to permit animals with unusual characteristics to persist because predatory animals, which elsewhere would elminiate them shortly after they appeared, are absent. Further, as a result of inbreeding, these unusual characters tend to be disseminated among a greater number of individuals on an island, so that any recessives, such as albinism, would have a greater possibility of appearing than they would among a similar population on a continent. These environmental and genetic characteristics are present on Lanai, so that here a unique example of the *modus operandi* in the evolution of an oceanic island fauna is available for study.

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HETEROKARYOSIS AND HORMONES IN *NEUROSPORA*

MOREAU and Moruzi (1931, 1932) demonstrated the existence of hormones in *Neurospora* by growing a sterile wild strain (incapable of forming perithecia when grown alone) in one arm of a U-tube and a unisexual strain obtained from Dodge in the other arm. Hormones from the "unisexual" arm passed into the "wild" arm and perithecia were produced in the "wild" arm. Dodge (1931) and Aronescu (1933) failed to duplicate this experiment and concluded that hormones are not produced. They imply that Moreau and Moruzi did not use aseptic technique.

The writer (1934a) has confirmed the existence of hormones in *Neurospora*. A bisexual, heterokaryotic, self-sterile strain (containing f+ and f− nuclei which were incapable of copulation because of sterility factors) was mated to a highly fertile mutant strain (F+). Two kinds of zygotes resulted: (1) f+/f− and (2) F+/f−. Hormones from the F strain had enabled the sterile strains to copulate. Moreau and Moruzi assumed that their wild strain was homokaryotic and that hormones had stimulated it to reproduce parthenogenetically. It was probably bisexual and self-sterile and the hormones probably supplied an essential substance.

In Dodge and Aronescu's experiments homokaryotic (+) and (−) strains were used in the two arms of the U-tube. Such an experiment can not test the production of hormones. They also used single-conidium cultures of the Moreau and Moruzi wild strain in an attempt to reproduce Moreau and Moruzi's experiment. Such an experiment is particularly liable to fail because, by making single-conidium isolates, the heterokaryon is easily separated.

Since sterility factors have a definite survival value in nature (Lindegren 1934a), wild strains are often bisexual as a result of mycelial fusions but self-sterile. Dodge (1935) disagrees and cites Köhler (1930), who failed to produce bisexual strains by allowing mycelia of opposite sex to grow together. Dr. Dodge kindly sent the writer five "wild" strains of *N. crassa*. One of these was from Mexico and bore the label A. One was from Cuba, also labeled A. Two were from Japan. These were labeled A and B, respectively. One was from Panama, labeled B. The strains Cuba A, Mexico A and Japan A were bisexual self-sterile heterokaryons. The Japan B and Panama B strains were unisexual. "Wild" mycelia must be tested against tester strains of both sexes. Aronescu (1934) tested the Moreau and Moruzi strain against testers of both sexes and reported that it was sex A, while Moreau and Moruzi had reported it as sex B. Apparently the two components of the heterokaryon had been separated before Aronescu obtained the strain. Including the Moreau and Moruzi strain, the writer submits that four of six "wild" strains were bisexual, self-sterile heterokaryons. This heterokaryosis could only develop as the result of mycelial fusions. Heterokaryosis often develops in the laboratory by mutation (Lindegren, 1934b; in press), but in 20,000 single ascospore cultures no bisexual heterokaryosis occurred spontaneously.

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A RAPID METHOD FOR MAKING PERMANENT MOUNTS OF DROSOPHILA SALIVARY GLAND CHROMOSOMES

TEMPORARY mounts of Drosophila salivary chromosomes in aceto-carmine will rapidly become too dark for use unless the slides are kept in solution of half-saturated aceto-carmine. It is inconvenient to keep large quantities of slides this way. Furthermore, the gum mastic-paraffin seal is partially dissolved in time under these conditions and the preparation may be lost when the coverslip falls off. Another serious difficulty is the fact that the index of refraction of the medium in which the chromosomes are mounted is quite different from that of the slide and coverslip. It is therefore impossible to make accurate observations of the finer structures of the chromosomes.

Permanent mounts of such preparations have been made by floating the coverslip off in half-saturated aceto-carmine, then dehydrating and mounting in balsam. The difficulties with this procedure are: (1) that a good deal of material is lost on removal of the coverslip; (2) the original fixation image may be altered during the dehydration so that the outlines of the chromatic bands are no longer sharp; and (3) a good deal of time and labor must be spent in order to produce a single slide.

To overcome these difficulties the following technique was developed:

(1) A saturated solution of aceto-carmine is prepared by boiling carmine in a 45 per cent. aqueous solution of glacial acetic acid for several hours. A reflux condenser is attached to the flask containing the solution in order to prevent changes in concentration by evaporation. A clear dark red solution is then obtained, either by sedimentation or filtration. No iron is added at any time.

(2) The glands are dissected out and stained in deep depression slides for not longer than fifteen to twenty minutes. If left for a longer period the chromosomes become fragile and can not be well stretched.

(3) The glands are mounted on a microscope slide and washed with fresh aceto-carmine to remove any debris that may be present. They are then covered with a square coverslip and the excess fluid taken up with blotting paper.

(4) The chromosomes are then spread by pressing on the coverslip with a dissecting needle. The coverslip must not be allowed to slide or the nuclei will be rolled into dense useless masses. This is easily prevented by pressing firmly on one corner of the coverslip with the finger. This step is executed under a dissecting microscope so that each nucleus may be observed and adequately spread.

(5) A saturated solution of carmine in glycerine is then put around the coverslip and a piece of absorbent paper placed against one edge of the coverslip. The slide is then put away until the glycerine has displaced all the aceto-carmine under the coverslip, usually over night. The glycero-carmine solution is prepared by dissolving the carmine in warm glycerine and then filtering. If ordinary glycerine is used in this step, the preparation will fade after a few days.

(6) The slide is immersed in alcohol to remove the excess glycerine and then blotted. It is then sealed with balsam, gum mastic-paraffin or any other suitable seal.

By this technique it has been possible to mount three hundred glands in two days and have them all preserved in excellent condition for observation. After one month there has been no noticeable change in the chromosomes. Furthermore, it is possible by this technique to stretch the chromosomes a great deal without breaking them. In a preparation made this way, Dr. C. Bridges has been able to detect seven new bands in a relatively short section of the X chromosome.

If it is desired to mount the glands in balsam, the slides may be allowed to stand with the glycerine for a day or two longer. The coverslip can then be readily slipped off, or pried off with a fine needle, or floated off in absolute alcohol. It is then cleared in clove oil and xylol and mounted in balsam. The loss of material by this technique is much less than with the usual method of removing the coverslip in aceto-carmine.

I wish to thank Dr. C. Bridges and Dr. F. Schrader for furnishing the microscopes necessary to make these observations.

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CULTURING PROTOZOA

A RECENT article[1] on culture methods has received many responses, and it is thought that these additional methods may also prove useful.

VORTICELLA

This recalcitrant form has been cultured successfully by the following method: Triturate 0.5 gm of boiled fresh egg yolk in just enough of solution A[2] to yield a thin smooth paste. Wash the paste into 1 liter of solution A and allow to stand for 2 to 3 days. Agitate thoroughly so that a fine yolk suspension is formed. With this a number of cultures may be started. About 60 cc together with some 50 Vorticellae are introduced into a thoroughly cleaned finger bowl. In about two weeks a fairly rich culture is found covering the bottom of the finger bowl. To maintain the culture it is advisable to pour off the old supernatant culture fluid, carefully rinsing the specimens (adherent to the bottom) several times with distilled water before adding 60 cc. of a new two-day old egg yolk suspension. This frees the culture of an excess of the free-swimming forms, which otherwise would tend to displace the Vorticella, and gives a relatively pure culture of the desired form.

To start a culture, it is not necessary to use a "pure" culture of Vorticella. A mixed culture will serve very well since, after a day or so, the other protozoa can be rinsed away.

If one desires a richer culture, more egg yolk may be used initially. However, such a medium frequently develops mold, is difficult to examine and does not have the longevity of the more dilute cultures.

BLEPHARISMA AND SPIROSTOMUM

These ciliates can be cultured successfully by the method previously described for Arcella.[1]

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[1] Paul F. Brandwein, AMERICAN NATURALIST, 69: 628, 1935.

[2] NaCl 1.20 gms, KCl 0.03 gms, $CaCl_2$ 0.04 gms, $NaHCO_3$ 0.02 gms; phosphate buffer solution, pH 6.9–7.0, 50 cc., distilled water to 1,000 cc.